March 1960

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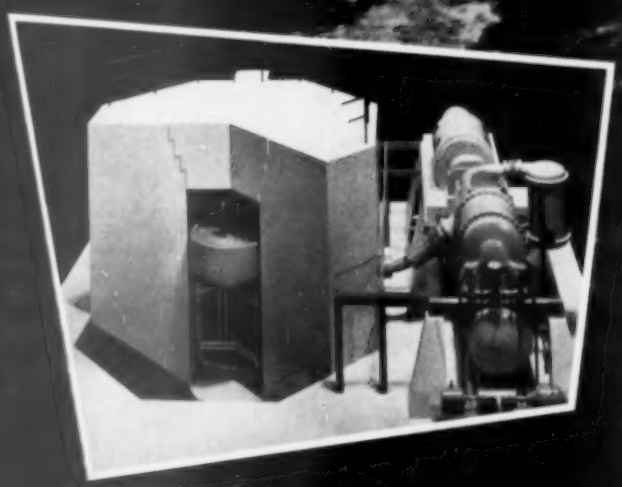
NUCLEONICS

ATOMIC POWER • NUCLEAR ENGINEERING • APPLIED RADIATION



GAS-CYCLE REACTORS FOR POWER

A Special Report

page 33

NOW

a *new* wire wound potentiometer

The mechanical and electrical features of Type 2W Rheostat-Potentiometer are designed for current and future electronic circuits. This modern, 2 watt unit offers maximum application adaptability plus typical IRC superior performance. Electrical operation is improved by one-piece center terminal and collector ring, and direct contact between collector ring and contactor. Advanced mechanical design anchors winding securely to strip, locks element into position, and assures accurate location of terminals.

IMPROVED DESIGN FEATURES

- **Better Heat Dissipation**
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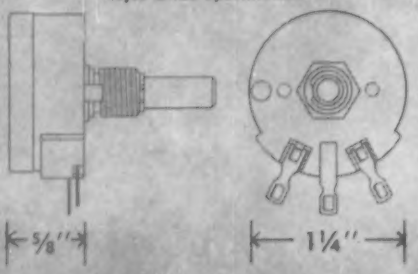
- **Increased Mechanical Rotation**
- **Increased Electrical Rotation**
- **More Resistance Values**
- **Double and Single Taps Available**

Equivalent To JAN-R-19
Style RA20 Specification



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Smaller and More Compact

2 Watt Power Rating — Based On 60°C. Rise Above 40°C. Ambient

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In Canada: *International Resistance Co., Ltd., Toronto, Licensee*

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Title _____
Company _____
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NUCLEONICS

MARCH • 1956

Vol. 14, No. 3

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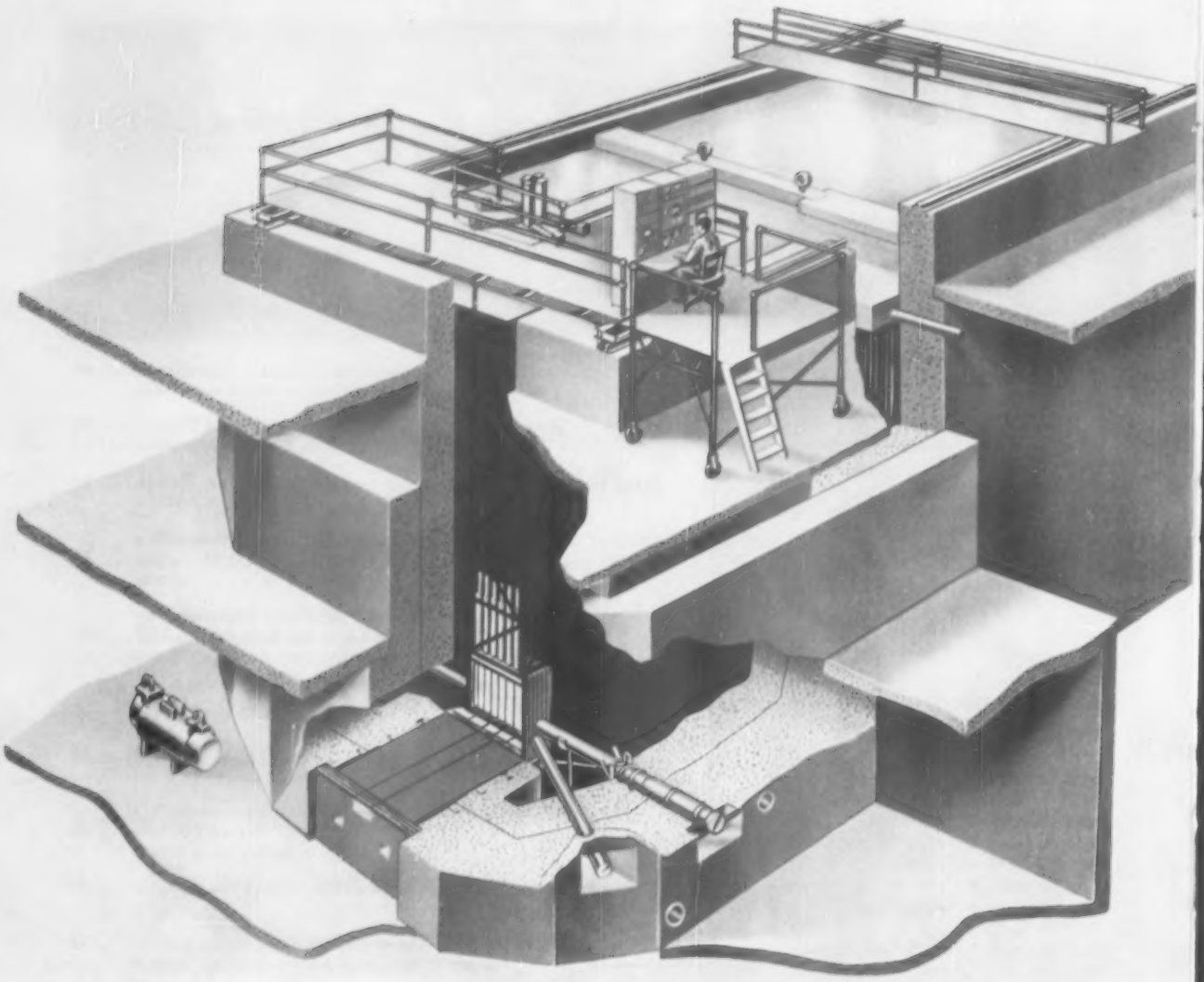
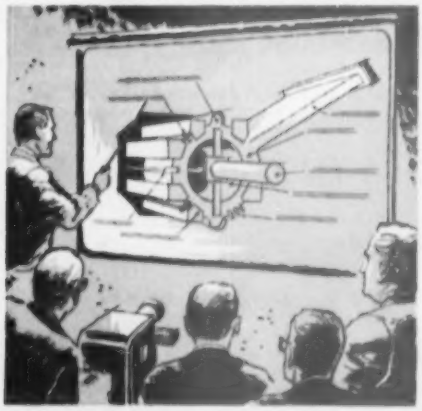


SWIMMING POOL REACTOR, one of three G-E research reactors available under the 7-point program, is designed to produce large quantities of neutrons. Its flexibility, safety features, and high flux potential appeal to universities and research organizations.

NEW GENERAL ELECTRIC 7-POINT PROGRAM:



1 REACTOR SPECIFICATIONS are prepared to meet your research requirements. These include a report on core, control, and reactor components.

2 BUILDING STUDY also includes complete co-ordination of all plans for the many facilities required in the reactor and laboratory buildings.

3 HAZARDS SUMMARY REPORT: We help you prepare study for submission to AEC Division of Civilian Application.

How General Electric can help you enter advanced nuclear research fields

New G-E 7-point program simplifies procedure for obtaining a nuclear research reactor

There is more work involved in obtaining a nuclear reactor for advanced research than simply ordering one. Specific research requirements must be determined beforehand, an appropriate design selected, and necessary AEC construction permits and licenses obtained. Other essential steps are covered in the program outlined below.

NEW GENERAL ELECTRIC 7-POINT PROGRAM is a plan designed to materially aid you in putting a research reactor to work. Through this program you can obtain any one of three General Electric research reactors: The Swimming Pool Reactor, Heavy Water Research Reactor, or the Nuclear Test Reactor.

FOR MORE INFORMATION on these three research reactors and the new General Electric 7-point program, write for bulletin GEA-6326, General Electric Company, Section 191-1, Schenectady 5, N. Y.; or contact your nearest G-E Apparatus Sales Office. Outside the U. S. and Canada, write to: International General Electric Co., Inc., 570 Lexington Ave., New York, N. Y.

Progress Is Our Most Important Product

GENERAL ELECTRIC

4 MANUFACTURE OF REACTOR is accurately co-ordinated with other construction plans, thereby assuring centralized project scheduling.

5 REACTOR INSTALLATION is completed at the site by the men who have followed the design and manufacture of the complete system.

6-7 START-UP AND SERVICE by experienced personnel is added assurance that proper operation of your nuclear system will be maintained.

General Electric EM* Pumps . . .

Move liquid metals with greater safety and continuity

. . . OPERATE WITHOUT MOVING PARTS, SEALS, OR BEARINGS

General Electric electromagnetic pumps, first designed for radioactive and high-temperature systems, are now used in liquid metal laboratories and industrial processes where minimum leakage and continuous operation are important.

Now designed to pump liquid metals at temperatures up to 1500 degrees F and to move up to 10,000 gallons per minute with accurate control of flow, General Electric EM pumps can be used to move such metals as sodium, sodium potassium, lead, bismuth or mercury.

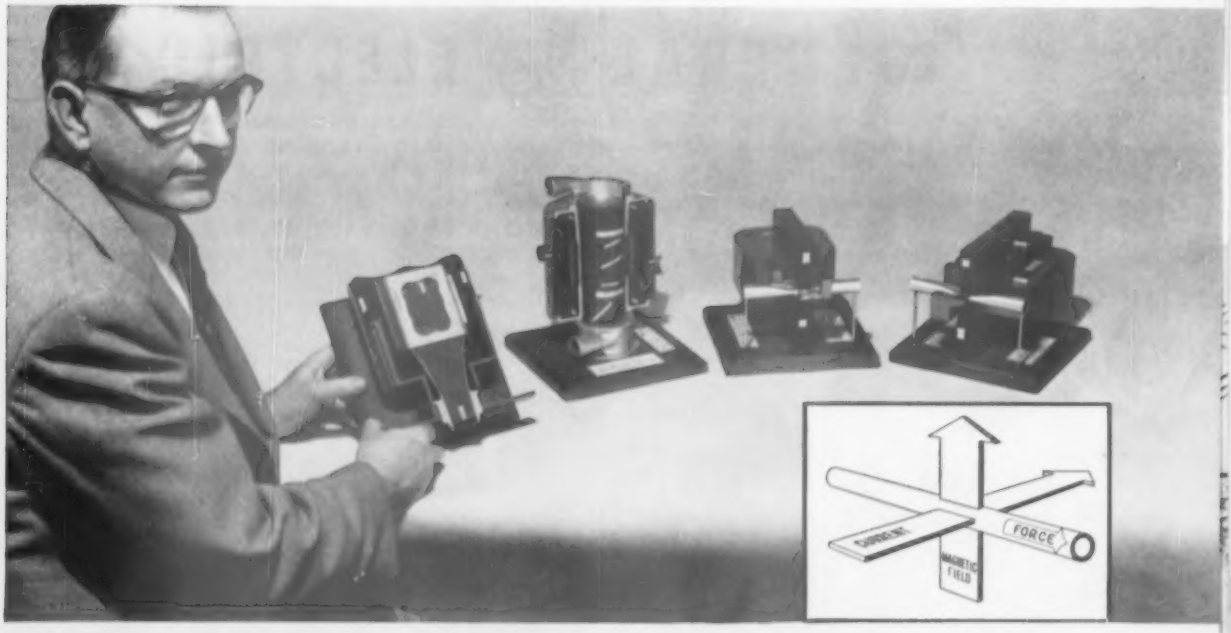
***Electromagnetic**

General Electric offers complete liquid metals pumping systems including EM pumps, magnetic flowmeters, liquid level indicators, pressure transmitters, induction heaters, cold traps, plugging indicators and sodium oxide control stations.

For more information on liquid metals pumping systems and components, contact your nearest G-E Apparatus Sales Office, or Section 193-1, General Electric Company, Schenectady 5, New York. Outside of the U.S. and Canada write to: International General Electric Company, Inc., 570 Lexington Avenue, New York City, N. Y.

Progress Is Our Most Important Product

GENERAL ELECTRIC



FOUR GENERAL ELECTRIC EM PUMP MODELS are shown by J. F. Cage, Manager—Component and Coolant Systems Engineering Operation, Atomic Power Equipment Department, (l. to r.): linear induction, helical flow, d-c, and a-c types. Diagram shows pumps' operating principle: Force is exerted on current-carrying liquid in magnetic field.

LIQUID METAL LOOP tests sodium potassium (NaK) in a G-E electromagnetic pumping system for use as heat-transfer agent. Loop's a-c EM pump (below) operates at 600 degrees F with capacity of 30 gallons per minute. Magnetic flowmeter (left of pump) measures flow externally, providing greater safety.

GENERAL ELECTRIC

CVC's model LC1-14 high-vacuum system measures 39″ by 30″ by 88″ with a chamber 14″ in diameter, 24″ high. It produces a pressure of 0.5 micron Hg in five minutes. High-vacuum valve isolates diffusion pump while chamber is opened to atmosphere.

How one economical package

fills all your laboratory needs for high vacuum

A *CVC* packaged high-vacuum system quickly creates a low pressure environment for metallizing optics and other materials, for melting metals, for degassing liquid compounds, and for a variety of other laboratory needs.

With every *CVC* system, performance is swift and dependable; each system offers:

- The proper size oil-diffusion pump in combination with mechanical pump to evacuate the all-glass chamber quickly to a fraction of a micron.
- The correct vacuum gauges to follow the evacuation cycle.
- Complete controls for electrical equipment, including a series of air-tight but current-conducting feedthroughs in the chamber.
- Jack panels for switching to different voltages or different sets of electrodes (optional).
- And, if you like, such accessories as rotating seals, glow discharge electrodes, and high-frequency power feedthroughs.

Write for an illustrated data sheet on the *CVC* LC1-14 shown above and the larger LC1-18 shown right.

Essentially the same as the LC1-14 high-vacuum system, the LC1-18 offers a larger chamber (18″ by 30″), and produces an ultimate pressure of 3×10^{-5}mm Hg with a 13 c.f.m. mechanical pump and a six-inch CVC oil-diffusion pump. Hoist is standard on the LC1-18, optional on the LC1-14.

Consolidated Vacuum, Rochester 3, N. Y.

a division of CONSOLIDATED ELECTRODYNAMICS CORPORATION. *Pasadena, California*

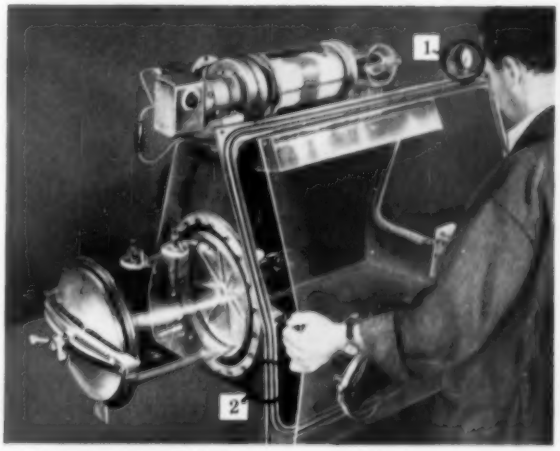
Sales Offices: Albuquerque • Atlanta • Boston • Buffalo • Chicago • Dallas • Detroit • New York • Palo Alto • Pasadena • Philadelphia • Seattle • Washington, D.C.

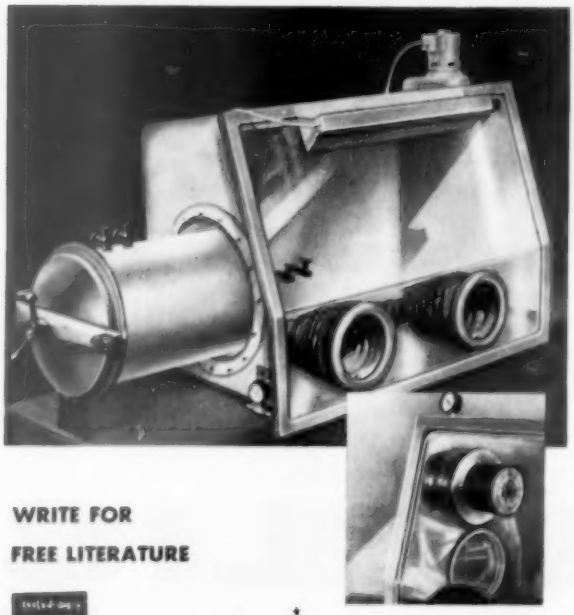
"LEAD-RUBBER" GLOVES that permit handling of low levels of beta radioactive materials. The gloves are soft and as pliable as heavy leather. They are made in a choice of thicknesses equaling 1 to 5 mm. lead shielding. They are designed to fit standard "O" ring systems employed in "Dry-Glove" boxes.

NEW TOOLS

for the Nuclear Industry

No. 13 "SAFETY-GLOVE" BOX. Transparent plastic housing with ¼" thick chemical and scratch resistant observation-glove panel. Shown is the simplicity in removing the 36" x 24" front observation-glove panel from the Safety-Glove box. Note the air gauge (1) and the inflatable plastic gasket-tube (2) which encircles the "Box." The patented inflatable gasket system allows the opening and closing of the entire "Dry-Box" to and from a hermetic state within seconds.





TWO SIZES: 36" x 24" x 18", 48" x 30" x 20".

"SAFETY-GLOVE" BOXES are now cast into a one piece "bottle like" housing of unbreakable and high heat resistant Polyethylene. The housing can be steam sterilized and has excellent chemical resistance. It is absolutely impervious to all acids. It is light and portable. Stainless steel housings are also available — with the same Lennard patented features and controls.

A new filter system with an efficiency of 99.98 on 0.3 micron dust particles. The system is composed of an internal and external filter housing with two disposable filters. The dust particles are trapped within self-contained filter housings and disposed of in a polyethylene bag.

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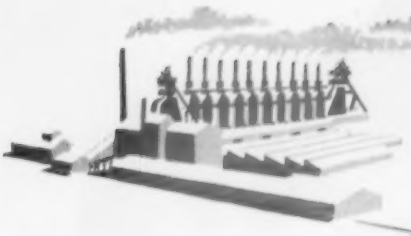
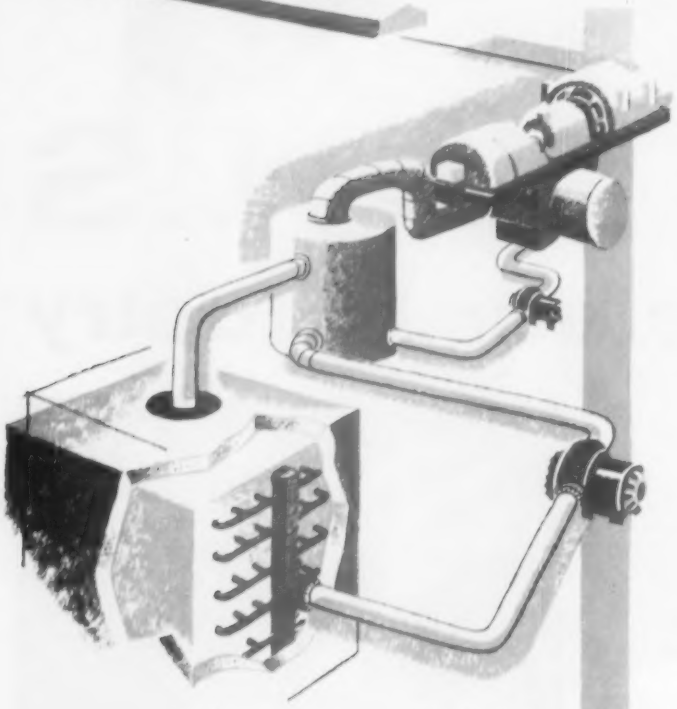


Atomic energy as

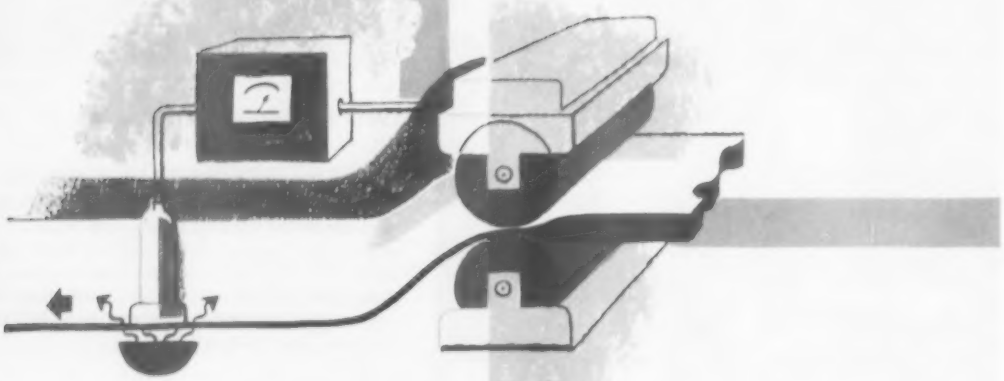


...as a fuel

Atomic energy may soon be used as the source of electric power for steelmaking, and perhaps eventually as a means of making steel directly from iron ore.

...as a tool

Radioactive isotopes are being used to determine wear on steel-mill structures and equipment, to improve steel quality, and to study steelmaking processes.



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World's Widest Range of Standard Steels

CLEVELAND 1,

a fuel...a tool...a market

...at REPUBLIC STEEL

The centuries-old iron and steel business is learning a lot these days from the decade-old atomic energy business . . . and putting this knowledge to use in many ways. For instance . . .

At Republic Steel, radioactive isotopes are already at work gaging the thickness of steel strip even while it moves at 1,400 feet a minute from the end of the continuous rolling mill.

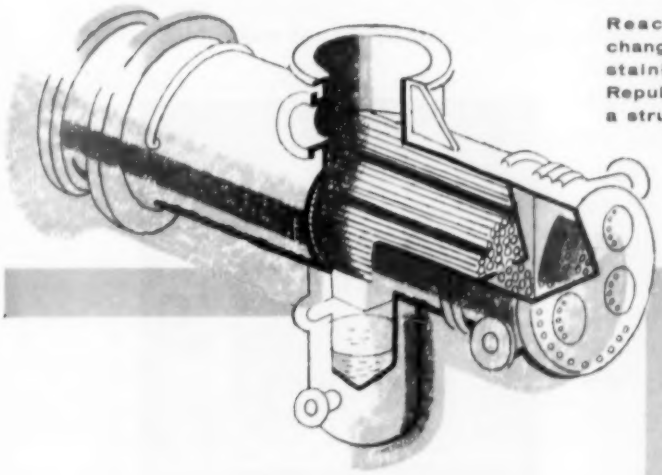
At another Republic Steel plant, our Nuclear Physics staff is giving long-range consideration to nuclear power as a replacement for fossil fuels in converting iron ore to steel. Completely new concepts of steelmaking may come from these investigations.

At the same time, Republic Steel's Marketing Divisions are promoting and selling Republic stainless steel, alloy steel, and titanium to designers and manufacturers of instruments, heat exchangers, reactor components, and other equipment for the atomic energy industry.

Republic Steel's Nuclear Physics staff is working with Republic's research, production, and sales departments to develop atomic energy uses as tools, fuels, and markets for Republic Steel. We believe that we can help you . . . a card or letter will start things happening.

...as a market

Reactor components such as heat exchangers and vessels are made from Republic stainless steel plate, sheet, and tubing. Republic Titanium also shows promise as a structural material for atomic equipment.

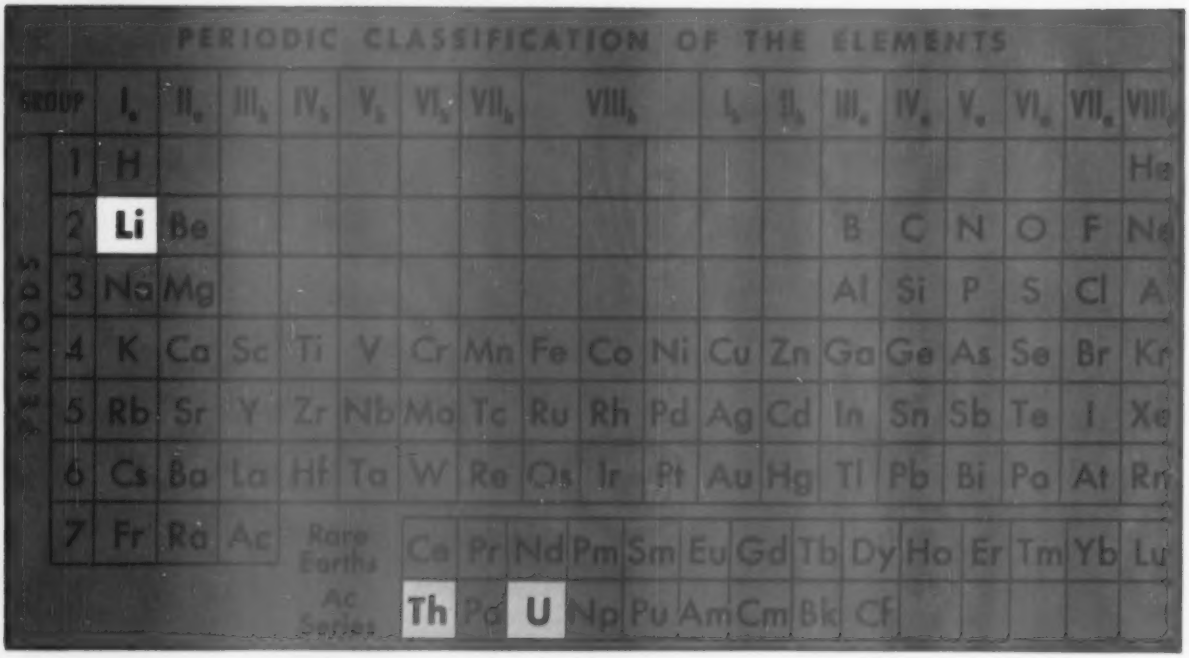


...Write for the free booklet which describes Republic Steel's interest in atomic energy and nuclear physics. Ask for "Booklet N-56A."

STEEL

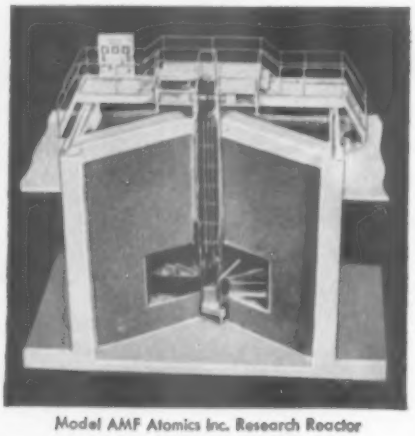
and Steel Products

OHIO



LITHIUM in the ATOMIC FUTURE

Only in recent years has mention of Lithium in nuclear energy been made. For the past 12 years, however, the technical staff of Lithium Corporation has been accumulating know-how on lithium. The contributions made to the comparatively small store of knowledge on this interesting element are material. Now, with our country on the threshold of peacetime nuclear power, Lithium Corporation stands ready to assist the creators of tomorrow's power. Lithium metal, two metal derivatives, and 15 salts are available for study. You are invited to share the benefits of our use-research into lithium. Write for technical data sheets on this miracle element. It could mean a great deal to you.



Model AMF Atomics Inc. Research Reactor

. . . trends ahead in industrial applications for Lithium

LITHIUM CORPORATION OF AMERICA, INC.
2595 RAND TOWER
MINNEAPOLIS 2, MINN.

MINES: Keystone, Custer, Hill City, South Dakota • Bessemer City, North Carolina • Cat Lake, Manitoba • Ames Area, Quebec • BRANCH SALES OFFICES: New York Pittsburgh • Chicago • CHEMICAL PLANTS: St. Louis Park, Minnesota • Bessemer City, North Carolina • RESEARCH LABORATORY: St. Louis Park, Minnesota

New Homogeneous Reactor

for LOW-COST ATOMIC POWER

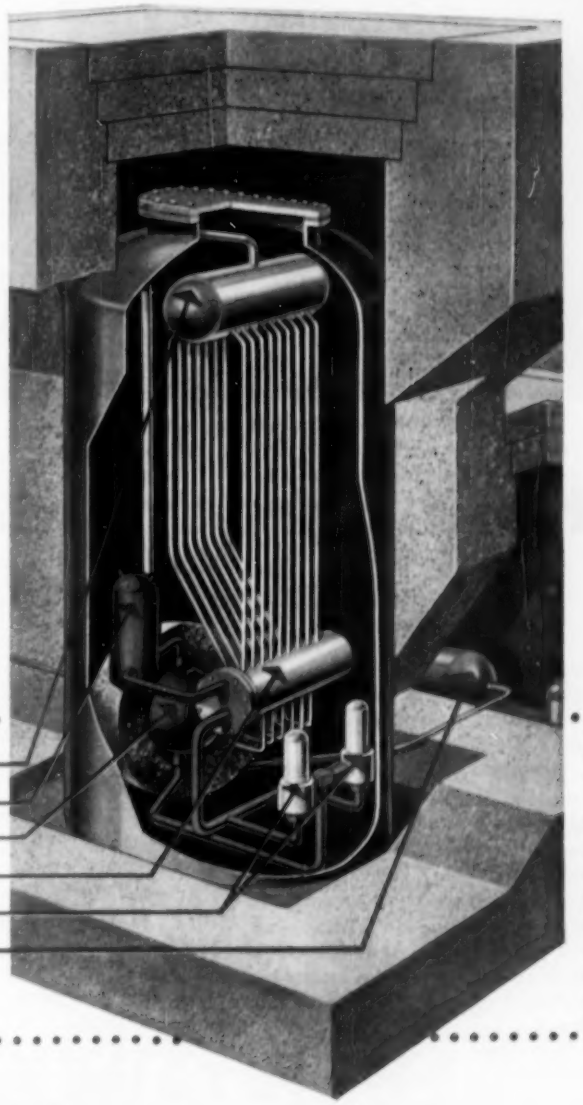
in the 5,000 to 40,000 kw output range

Simplicity of design, exceptional stability and ease of control are outstanding features of this small homogeneous power plant

The one-region aqueous homogeneous reactor illustrated in the cut-away drawing at the right has been designed by Foster Wheeler for economical production of electric power in the 5,000 to 40,000 kw range. It offers these unique advantages.

1. Reactor design is based on optimum nuclear parameters rather than heat removal.
2. Continuous chemical purification of the liquid reactor fuel removes fission and corrosion products.
3. No control or safety rods are necessary. Large negative temperature coefficient of reactivity enables reactor power to follow load demands rapidly and faithfully.
4. Reactor vessel is a simple, spherical pressure vessel.

Liquid fuel is pumped from the reactor to a heat exchanger and the steam thus generated can be superheated and used to drive a conventional turbo-generator. For more complete information, send for a copy of the November issue of Heat Engineering. *Foster Wheeler Corporation, 165 Broadway, New York 6, N. Y.*



(HOT portions of circuit shown in red)

FOSTER WHEELER

NEW YORK • LONDON • PARIS • ST. CATHARINES, ONT.

Removing parts from Inconel retorts subject to sustained high-temperature attack. Inconel doubled life of retorts.

Heat agrees with this Inco alloy

. . . long after other metals fail

Want a metal that resists sustained assault by heat and corrosives?

Look to Inconel* nickel-chromium alloy.

Take the carburizer shown above, for example. It encounters conditions as severe as those in many atomic-energy applications. It operates twenty-four hours a day at 1700°F. in a carburizing atmosphere. It experiences thermal shock in loading and unloading. In this demanding application, Inconel alloy retorts last twice as long as those made of other metals.

Service records like this show why Inconel alloy is used in high-temperature processing of all kinds.

Now nuclear engineers are turning to Inconel

Inconel is structurally stable. It is not subject to embrittlement on prolonged heating.

Inconel is chemically stable. It resists damage by oxidation, carburization and other forms of high-temperature attack.

Inconel is mechanically stable. It retains useful properties to 2100°F., and over in some applications. It resists grain growth and withstands thermal shock.

Inconel is easy-to-work . . . easy to form, machine, weld . . . available in all commercial wrought forms.

*Registered trademark

Any hot metal questions?

Resolve them with Inco's 24-page Technical Bulletin T-7. Packed with facts about the physical constants, properties, working characteristics, and mill forms of Inconel and Inconel "X" (age-hardenable nickel-chromium alloy). Yours for the asking.

So are the advice and help of Inco's Technical Service Section. Just write:

THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street New York 5, N. Y.

INCO Nickel Alloys

Inconel . . . for long life at high temperatures

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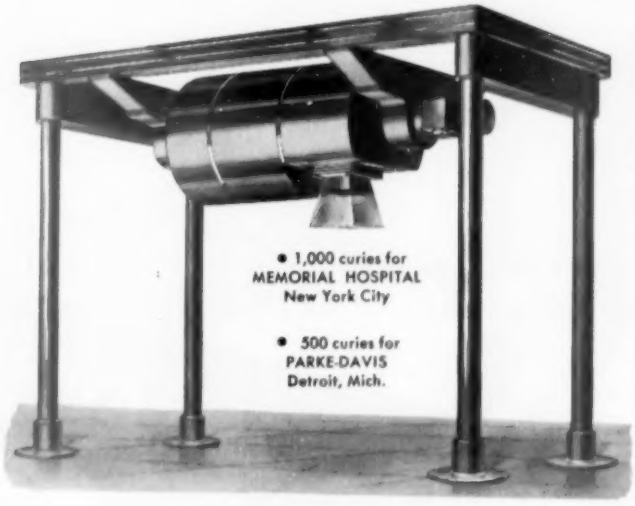
Measurements made at 75 K.V. and 0.5mm Aluminum gave the following results:

	% transmission	lead equivalent
1 layer	15	.040mm
2 layer	6	.088mm
3 layer	4	.140mm

Archer Lead Glass cloth is very effective in light weights. It is a flexible, strong, chemically resistant, fireproof material. Archer cloth will not deteriorate in storage or use, is non-shrinking and non-allergic.

MEMORIAL MODEL "CORAY" CO^{60} IRRADIATOR

Engineered by BAR-RAY with U.S. ATOMIC ENERGY COMMISSION



- Floor, wall or ceiling mounted
- Remote automatic operation or to suit special requirements
- Designed for continuous use
- Wide range of cone fields available
- Larger fields at shorter focal distance
- Designed for standard AEC capsule
- Meets all safety requirements of National Bureau of Standards new Handbook 54 and Atomic Energy Commission
- Economically priced from $3,000 to $12,000

A complete range of Cobalt^{60} irradiators for therapy, industry and research are available in six basic models from 250 to 1,000 curies.

CORNING RADIATION SHIELDING GLASS

Bar-Ray is distributor for this 3.3 density, non-browning and 6.3 density lead glass. The 3.3 glass will not discolor when exposed to high level radiation. It has mechanical strength comparable to commercial sheet glasses and excellent chemical stability. A variety of sizes are available in thicknesses of 2", 3", 4", 6" and 8".

BABCOCK & WILCOX FLEXIBLE FILM HOLDER

Bar-Ray is manufacturing licensee for this heavy duty, flexible, light type enclosure for x-ray sheet film, for use with direct exposure and with lead screens. Fabricated of durable black plastic and hinged with black plastic tape. Double fold-over in construction, it is 100% lightproof. Accommodates films and screens in all sizes. Special sizes to order.

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Stainless Steel Processing Systems • Isotope Fume Hoods and Labs • Film Transfer Cabinets • Thermostatic Valve Assemblies
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Your May sales message in NUCLEONICS for advertising radioisotope products and services will have greater impact and longer lasting value. A "first-time," 32-page report will examine the practicability and *economic importance* of specific industrial applications. This handbook-type reference compilation will cover Research, Large Scale Industrial Tracing, General Use of Isotopes in the Field of Hydraulics, Wear Studies Employing Tracers, Isotope Dilution and Tracer Analysis, Activation Analysis, Beta Thickness Gaging (Transmission and Backscatter), and Density Gaging Using Gamma Sources. Schedule your May advertisement now . . . derive the benefits of tying-in with an issue that will be *studied* for months to come, attracting industry-wide attention.

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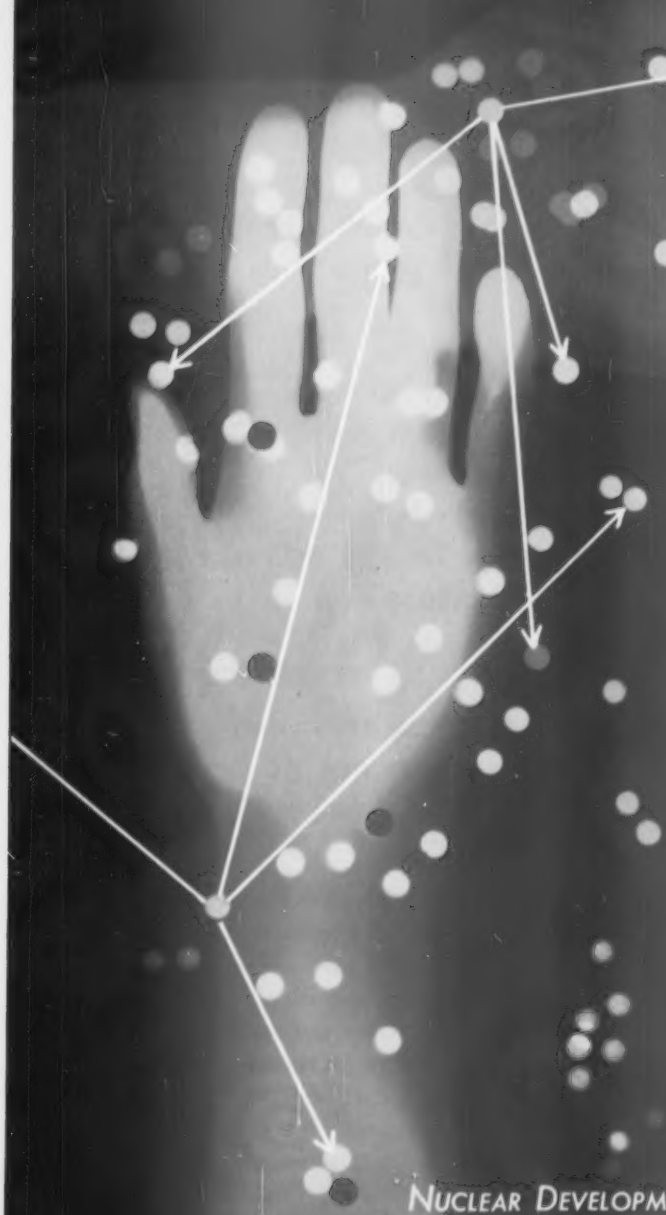
NUCLEONICS

NUCLEAR DEVELOPMENT CORPORATION OF AMERICA

HOW WE MEASURE A REACTOR'S FIRST HEARTBEAT

NDA_



A new reactor is conceived in a human imagination but it is born and is first alive as a "critical assembly" in a "critical" facility. Each reactor must undergo many exhaustive tests to establish safety and performance characteristics. The first such tests are conducted in a reactor critical facility at zero power under the direction and control of a skilled team of nuclear scientists, engineers and supporting technical personnel.

NDA is completing the country's first private industrial reactor critical facility at its Nuclear Experimental Station in Pawling, New York. Staff personnel are organizing and planning reactor critical experiments in connection with several reactor development programs under way at NDA.

NDA would be pleased to work with other reactor designers and builders in developing and conducting test programs utilizing this new reactor critical facility. Consultations on a program to meet your requirements are available without obligation.

NDA always welcomes inquiries from scientists and engineers interested in joining with us in this expanding field.

NUCLEAR DEVELOPMENT CORPORATION OF AMERICA

5 NEW STREET, WHITE PLAINS, N. Y. • TEL. WH 8-5800

ROUNDUP of Key Developments in Atomic Energy

LATE NEWS and Commentary

40,000 Kilograms

Long awaited, the announcement by the President last month that 40,000 kg of U^{235} would be made available for peaceful uses here and abroad contained so much vagueness on the conditions that might be attached to distribution that it was not clear whether the program would be a boon or bust to the U. S. One industry observer flatly said, "If we tie too many strings to our negotiations with foreign countries, this will boomerang on us."

Under this second annual "determination" required by Sec. 41b of the new act, half the 88,000 lb would be leased in the U. S. "for all licensed civilian purposes, principally for power reactors"; half abroad "through sale or lease for peaceful purposes, principally power and research reactors. This," the determination specified, "is in addition to the 200 kg already made available for research reactors abroad." Further, "it is not intended that nations which are presently producing U^{233}, or the Soviet Union and its satellites, shall share in this distribution." The first category rules out Britain.

In an accompanying statement, AEC chairman Strauss filled in a few of the holes. The metal "will not all be distributed in the coming year or in any other single year. It will be distributed over a period of years as needed, with smaller amounts in the early years. Licenses may be issued for a varying period extending up to 40 years, and delivery of U^{235} to licensees will be spread over the life of the licenses, to permit start-up of reactors and replacement of fuel as required in later years." He also said the authorization "was based on estimates of current and future needs. These include the needs of existing licenses and pending applications for licenses as well as proposals received by the Commission—including proposals under the power demonstration reactor program—which seem likely to lead to the filing of license applications during the current fiscal year ending June 30, 1958. . . . The U^{235} will be distributed under the provisions of Sec. 33 of the Atomic Energy Act of 1954 and will be allocated to specific licensees only on the basis of a Commission determination of the licensee's need for the material."

The statements begged a number of key questions, one of them explicitly: "The procedures which will govern the distribution of the 20,000 kg of U^{235} to be made available to other countries, as well as charges for sale-or-lease, will be announced in the near future." Points crying for clarification include:

Enrichment. Not a word on this in either Eisenhower or Strauss statements. The existing research bilaterals, covered by the earlier 200 kg allocation, each specify "up to 6 kg of contained U^{235} in uranium enriched up to a maximum of 20% U^{235}." For the larger amounts required to fuel power reactors, 20% enrichment had been considered dangerous—for diversion to weapons use—by the security-minded, but AEC is now leaning toward a 20% enrichment ceiling.

Reprocessing. Nor is there any clue in the statements whether return of spent fuel to the U. S. for reprocessing and plutonium recovery would be required. In a subsequent radio interview, however, Strauss said U. S. reprocessing would be required and that he "presumed" a U. S. representative would be stationed in each foreign plant using our U^{235}. Sen. Anderson and others contend that this approach is technically impractical, economically and psychologically unsound, and that the U. S. would do better to make a show of confidence in its allies.

Ownership. The determination speaks of "lease" domestically, "sale or lease" abroad. The law lays down that the government must own all fissionable material in the U. S., but implies that sale is permissible abroad. This inconsistency may focus pressures for liberalization of the law's domestic ownership clause.

World agency. Although the determination was published on the eve of the meeting in Washington of the 12-nation committee to redraft a charter for the international atomic agency, no reference whatever is made to this proposed body —unless the prohibition on granting U^{235} to the Soviet bloc is viewed as a negative reference. However any role of world uranium-dispenser that may once have been contemplated for the agency has now been dropped because of lack of confidence between East and West.

Euratom. Another international angle is the effect the determination may have—and may have been intended it should have—in deterring West European aspirations to build jointly their own U^{235} separation plants. The determination came on the eve also of a meeting of the European coal-steel pool nations to set up a parallel atomic pool, Euratom; one of the principal goals envisaged for this pool is the building of a joint gaseous diffusion facility.

Although 20,000 kg of U^{235} for domestic use may seem like a huge amount, a little pencil work quickly cuts it down to size. The six power projects now underway (Shippingport, Con Ed, Commonwealth, Detroit, Yankee and Nebraska) require a total of 2,759 kg of contained U^{235} *for their initial loadings alone.* Thus, if one assumes a 1-year average fuel cycle, the 20,000 kg will barely feed these six plants for seven years—let alone the 40-year license period of which Strauss spoke, and let alone any other projects.

•

The Zinn Resignation

The resignation last month by Walter H. Zinn as director of Argonne National Laboratory aroused a flurry of speculation on two points: (1) future of government-owned national atomic energy labs, and (2) future of Argonne specifically. With the growth of industrial activity in atomic energy, the question has been raised, particularly in connection with reactor development, whether AEC's labs should grow in size and in number of project-type programs.

Actually, because the Zinn resignation was related to an AEC decision on a particle accelerator project—Zinn denies this relationship—it does not necessarily point to any policy decision on the part of AEC as far as the future of the labs is concerned. In fact, the announcement had a reverse twist: it caused some Argonne personnel to worry about ANL's future in basic research, something which has never been questioned.

What happened on the accelerator project was this: AEC has been considering building two high-energy machines in the midwest—one a quickly-built 10–15-Bev job aimed at keeping us ahead of the Russians, who announced a big accelerator project at Geneva; the other a long-range project for an advanced type of machine. Midwestern Universities Research Association (a nonprofit cooperative group of 14 universities, including the University of Chicago, operator of ANL for AEC) has been trying for some time to get AEC support for a large accelerator, hoping that the machine could be built at a new center and not at Argonne. Zinn and AEC, up until recently, were against locating it away from ANL. Then AEC, with Commissioner W. F. Libby carrying the responsibility, tried to effect a compromise with the short-term project going to Argonne and the long-term one to be handled by MURA, presumably at its own site.

Although he told NUCLEONICS this was not the reason for his resignation, Zinn did resign (effective June 30) at about the time of AEC's decision.

Considered by many the country's greatest reactor designer, Zinn—director of Argonne since its establishment in 1946—was acclaimed the outstanding figure of the Geneva conference last fall. "The new and vigorous atomic energy industry owes much to the clarity of your thinking and the ingenuity of your work," AEC chairman Strauss wrote Zinn. At this writing Zinn has not decided where he's going.

Insurance Available for Reactor Liability Inadequate, Congress, Industry Agree; Rep. Price Asks Federal Aid

Insurance was the problem that dominated the first half of the annual "Sec. 202" hearings before the Joint Committee on Atomic Energy last month, highlighting the first two days when AEC leaders testified, and practically monopolizing the industry leaders' testimony.

Conclusion: presently available maximum third-party liability of $60-million is inadequate.

In reply to close Committee questioning, AEC general counsel Mitchell declared the Federal government would not be liable for any deficit in damages which a licensee is unable to meet, in case of a major mishap. But on the broader problem, Rep. Sterling Cole spoke for all: "It seems to me that this question of insurance is one of the most important in the whole field of licensing with respect to the progress of this business. If the applicants are going to be exposed to the liability in the extreme of a calamity, they are going to be discouraged from getting into it. We have to find some solution, unless everybody is agreed that the probability of accident in an atomic reactor is so very remote that we do not need to be concerned about a catastrophe."

Cole asked AEC to study the possibility of Congress limiting the liability of a licensee to meet damage claims occurring in the operation of the facility, as "one possible solution to this insurance problem." And Rep. Melvin Price introduced a long-discussed bill: to have the U. S. underwrite liability risk not covered at reasonable rates by private insurance carriers during the next 10 years.

Heads of three major civilian power-reactor projects now underway told the Committee that (in the words of William Webster of Yankee Atomic Electric Co.) "we doubt that adequate protection yet exists to justify our undertaking major construction expenditures."

"What we are really concerned about," said Willis Gale of Commonwealth, "is the extraordinary third-party liability from a major nuclear catastrophe. The likelihood of a major nuclear incident is extremely remote; but if it should occur, the potential damage might be extreme . . . Our proposal to AEC and our contract with GE (for a 180-Mw boiling water reactor) are conditioned upon the satisfactory solution of the insurance problem, at reasonable annual cost, before the end of 1957. Commonwealth, for one, cannot risk its solvency for a $35- to $40-million investment." Walker Cisler of Detroit Edison expressed similar views.

In another hearing highlight, Commissioner Thomas Murray warned we are falling behind Russia in the peaceful atom race, urged a crash program with the U. S. spending $6-billion to build 12-million kw of atomic power by 1965.

Seven Bid in Second Round of AEC Reactor Program

Although some had felt the second round of AEC's program of financial aid for private reactor builders was going to be a flop, events proved otherwise. One week after the Feb. 1 deadline for the second Power Demonstration Reactor Program, AEC announced it had seven bids. One came from a university, six from utilities—of which five were long considered and carefully planned. Numerically, at least, this compared well with the first round of PDRP in which three utility groups proposed nuclear power plants ranging from 75 to 134 Mw. The second round (NU, Oct. '55, p. 11) was limited to plants in the 5-to-40-Mw class.

A NUCLEONICS survey of the seven bidders' reasons for bidding and the background and preparation brought out a number of significant points.

- Each of the seven bids involves a different technical concept, with seven of AEC's eight approaches represented (all but fast breeder).
- The survey showed that a utility can become active in the nuclear field without having a staff nuclear engineer. None of the utilities have nuclear-trained personnel; nearly all said they approached the matter from the operating utility viewpoint and felt they could adequately assess the possibilities on that basis, while leaving details of reactor physics and engineering to their manufacturer or consultant.
- Of the six utilities, three are cooperatives and three municipal utility departments. (There had been some criticism of AEC that it was discriminating against public power, and those critics are now watching to see what AEC will do.)
- Three bidders took advantage of the broadened aid terms ("financing and retaining title to all or part of the reactor system," not available under the first round). Elk River, Wolverine and Piqua specifically say AEC would retain title to the reactors.
- Four bidders (Holyoke, Piqua, Orlando and Florida U.) introduced another new element to nuclear power by providing that in addition to the reactor, there would be a standby coal or oil heat source for the turbine to provide uninterrupted generating capacity during refueling and development work. This will yield strictly comparable cost data.
- Piqua's proposal is made contingent on successful completion of the AEC-Atomics International Organic-Moderated Reactor Experiment.
- Wolverine's proposal includes provision for an on-site chemical reprocessing unit for the highly-enriched uranyl sulfate D_2O solution.
- Wolverine also provides that, because of their concern over development of educational facilities in the nuclear field, "as part of our proposal we are inviting the nuclear physics department of various universities in this region to use our facilities to the widest extent possible."

For NUCLEONICS' survey of the proposals, turn the page.

Cole Asks A-Heat for Congress, Reactor under Capitol

Installation of a power-and-space-heat reactor underneath the U. S. Capitol became a distinct possibility last month when Sen. Clinton P. Anderson and Rep. W. Sterling Cole, chairman and former chairman of the Joint Committee on Atomic Energy, filed bills calling for a $200,000 feasibility study.

"The matter has been rather thoroughly explored and all persons who had given any thought to it are confident that the idea is not only feasible and practicable, but that it can be done economically as well," Cole said. His plan is for a 25-Mw reactor, buried beneath the present powerplant, to provide space heating in winter and electricity for air-conditioning in summer.

Seven Small Power Demonstration Bidders Tell

	Holyoke, Mass.	Orlando, Fla.	Gainesville, Fla.
Location	Holyoke, Mass.	Orlando, Fla.	Gainesville, Fla.
Organization	City of Holyoke	City of Orlando	University of Florida
Power (electric)	15 Mw	25-40 Mw	2 Mw
Reactor type	Closed-cycle gas turbine	Liquid metal fueled	Pressurized water
Builder or engineer	Ford Instrument Co.	?	Alco Products, Inc.
Scheduled completion	?	1960	1959
Average power cost now	11 mills	6.5 mills	——
Why organization submitted a bid: its philosophy on atomic power	"We have immediate need for added capacity. We would like to cooperate with AEC to further the art of nuclear power. But as a municipal department we have no risk capital; we have had to take this into account in preparing our proposal. "We are in a high cost fuel area. Any power at 11 mills or less looks good to us. We feel fossil fuels are on the way up, if anything. The possibility of nuclear fuel decreasing in cost is also good, as the technology of fuel fabrication and reprocessing advances. This is our hope: to hold down at least one of the advancing costs by the use of nuclear power. "We are not in it for research; we're in business to sell power. But if we can fit research into the picture and benefit our rate-payers thereby, we are glad to do so. We would feel delinquent if we did not investigate nuclear power: we feel it's our duty to do so. We've looked at a lot of numbers on conventional plants; they don't look good. We're intrigued with the overall plant efficiency that can be attained with closed-cycle systems. Some of the numbers are absolutely fantastic. "We will have two heat sources for the gas turbine, a conventional boiler side-by-side with the reactor, so we don't lose generating capacity during reactor refueling or if any work is necessary during the development phase. →	"We had just retained Black & Veatch of Kansas City as consulting engineers for our future power expansion. They were here to sign a contract just two days before the second round deadline, and suggested we file a bid—they thought it would be a good idea because of the high cost of fossil fuel in Florida. They had already prepared an application, and we had a 30-minute discussion on it. We did not make a long study—we are just taking our engineers' word for it that this can become a reality. Black & Veatch are contacting manufacturers."	"Dean of Engineering Joseph Weil feels the university, already working in radioisotope tracer techniques and other aspects of radiation, should get into nuclear engineering. He did much missionary work, and last year the state legislature appropriated $500,000 toward an engineering research reactor, estimated to cost about $2-million. When AEC announced the second round of the power demonstration reactor program, we felt it would be a good thing for us to get into: we could combine a demonstration power reactor with a research reactor. We plan to have research ports permitting irradiation work to be done. The design is a modified APPR, but with fuel of much lower enrichment: 18–20%. "We understand that under the terms of AEC's invitation we are not absolutely required to produce electricity—it is sufficient to produce steam. We could either feed the steam into the university's steam lines, or use the reactor as standby for a turbo-generator with conventional heat source which the university already has on order."
Aid asked of AEC	"Can't give exactly at this time. We propose to put into the plant up to the equivalent cost of a conventional plant."	"Because of the lack of time available before the deadline, it was not possible to fill out the application completely, especially as to the financial side. We have scheduled conferences with AEC, and will work the details out."	"Cannot give details now; by and large, a total of $900,000 is asked, covering some construction costs as well as r-&-d work, and not including fuel."
Number and training of those who prepared bid	"The project officer (gas dept. superintendent) and company attorney worked it out, with the manager supervising. There's also a staff nuclear study committee. None of us has nuclear training; we look at it from the operating power utility standpoint. None of us pretends he's a nuclear physicist; but we do have enough knowledge of power generation and distribution costs to analyze a situation like this if we get all the facts involved." →	"None of our personnel is in on this—it is entirely a suggestion from Black & Veatch and we decided to go along with them. We have no one qualified."	"About 50 all together worked on the proposal including radiation specialists and others rather remote from reactor work. Those with actual first-hand reactor training totaled about 10."

Why They Are Ready to Invest in Atomic Power . . .

Elk River, Minn.	Hersey, Mich.	Anchorage, Alaska	Piqua, Ohio
Rural Coop. Power Ass'n.	Wolverine Electric Coop.	Chugach Electric Ass'n.	City of Piqua
22 Mw	10 Mw	10 Mw	12.5 Mw
Boiling water	Aqueous homogeneous	Na-Cooled, D_2O-Moderated	Organic moderated
AMF Atomics, Inc.	Foster Wheeler Corp.	NDA	Atomics International (NAA)
1960	?	1961	1960
9.2 mills	9 mills	17 mills	5.67 mills

"Our faith in American industry and technical know-how makes all of us extremely confident that atomic power will be made economically, and very rapidly. The study and planning of our power association is always done ten years in advance, and so atomic power could not be neglected. The results our people have seen in attending the demonstration programs of the AEC fully indicate that power can be produced with atomic energy.

"The question of when complete competitive status in all areas will be achieved depends only on the amount of time in which actual construction of plants is delayed. Once experimental plants are built and the first mistakes analyzed and corrected, only then will we be in position to allow our productive know-how to bring atom power within the economic range of most of the areas of the U. S. Our cooperative is in a high fuel cost area. Gas is not available, coal must be transported from Kentucky, and freight rates have been on a steady increase."

"The Wolverine Electric Cooperative serves power to rural areas in the central part of lower Michigan. This area is termed a high cost fuel area, mainly due to the fact the natural resources of this area are not ample to supply the total demands; this results in importation of coal, oil and gas from other states. Therefore we are constantly endeavoring to seek better means to supply ourselves with more economical fuel. In fact as far back as 1950 our board of directors inquired as to the progress in the nuclear field with regard to the possibility of obtaining electrical power from this source of energy.

"Therefore it can readily be seen that our motive is very sincere in making his investigation. However we do not wish to take the stand that this is a selfish move for Wolverine only. It is our thought that if this demonstration program should materialize, the information will be of excellent value not only to utilities in the U. S. but foreign countries as well."

"It is our hope that a nuclear reactor can help solve many of the serious problems of power generation in the Alaska area where fuel costs, which in turn reflect high railway transportation costs, have resulted in very high cost of thermo-electric generation. For there will be a need for additional power in the Anchorage area in 1961–63, and a small nuclear plant may well generate cheaper power for Alaska than do presently available thermal sources. In the Anchorage area the 1955 average cost of power at the bus-bar was about 17 mills; in other parts of Alaska power costs run as high as 27 mills per kwh. Thus an operating plant with the necessary field operating experience has large promise in the development of power-starved areas of Alaska. There is an added possibility for a district heating system for the immediate downtown area of Anchorage which would make it possible to utilize low-pressure steam and waste heat from the proposed nuclear plant."

"We wish to contribute to the advancement of the art in utilizing nuclear fuels for peaceful pursuits. We believe municipal as well as private utilities should contribute their share towards engineering progress by assisting in experimentation and research.

"Operation of an experimental organic moderated reactor would serve to further the use of such units to the benefit of the ultimate consumer of electric and steam energy. The possible use of gamma rays from fission wastes (cooling fuel elements) in agriculture, sanitation and industry are also reasons for our direct interests. Conservation of natural resources will increase with the development of nuclear units for power production. Availability of nuclear power and nuclear by-products will, we believe, attract industry to this area to the benefit of all individuals in our community. Undeveloped potential uses of by-products such as the reduction in cost of sewage treatment, which will benefit the community as a whole, are attractive intangibles."

"We have proposed that AEC build the reactor and we will supply all turbo-electric facilities. A contract has also been requested for financing r-&-d activities. The cooperative over a given time will repay to the Federal government a substantial part of their total investment."

"Wolverine proposes to provide the site, the reactor containment, and all secondary loop facilities at an estimated cost of $1,088,000, to operate the plant and to purchase all fuel and related materials and to pay for all off-site fuel processing. AEC is being requested to finance the r-&-d program . . . of →

"Chugach Electric will pay a substantial portion of the construction cost and will operate the entire plant. Whether AEC would have title has not been decided.

$1,302,000, and to construct and retain title to the reactor, including processing facilities, (for) $2,486,000."

"We are proposing that AEC pay only the excess charges associated with nuclear generation, that the City of Piqua take full responsibility for operation and maintenance of the installation without profit. AEC would retain title to the installation and could terminate the experiment at any time."

RCPA relied on AMF Atomics for the nuclear planning, and on two engineering consultant firms; RCPA's production engineer and planning engineer also worked on the proposal, but no one in RCPA has nuclear training.

The manager of Wolverine and an outside consultant engineer handled preparations for Wolverine. "Neither of us has any regular nuclear training, but of course we went down to Oak Ridge and took a couple of short courses. We went out, in a management capacity, and talked to nearly all manufacturers that are proposing reactors."

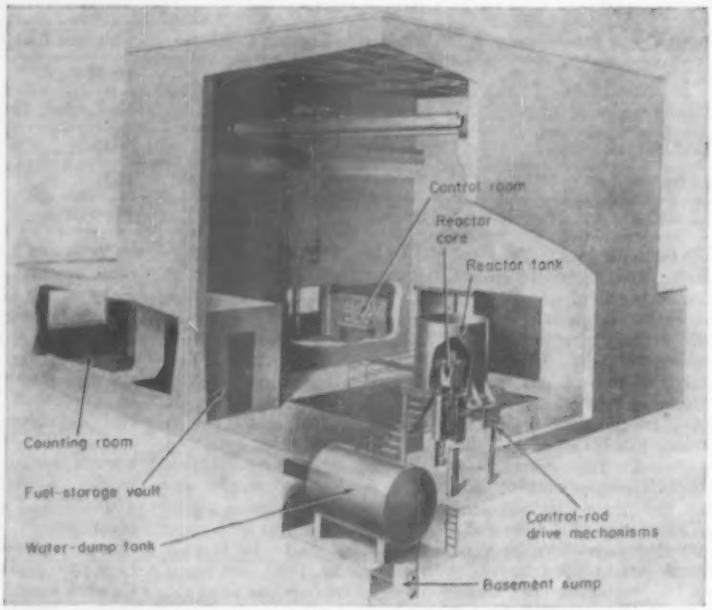
"A total of about 25 technical people worked on the proposal, 10–12 from Chugach, 10–15 from Nuclear Development of America. The Chugach personnel had no reactor background in the specific sense; they did, however, do much work on site choice, potential operating methods and needs, and on the power plant portion. →

Piqua's Director of Utilities, the only person who worked on preparation of the proposal and in direct nuclear planning, is an electrical engineer and a consultant on steam production, power supply, transmission and distribution.

NDA provided the reactor technical knowledge."

ROUNDUP

ALCO'S CRITICAL EXPERIMENT facility, under construction at Schenectady, is shown here in cutaway. To be completed in May, the zero-power reactor with associated nuclear laboratories will cost $230,000 fully equipped. Vitro Engineering Corp. is project engineer. Facility is being built in connection with Alco's Army Package Power Reactor project, to test fuel elements and control rod drive mechanisms for APPR. Object is to expedite APPR by permitting testing of components in advance, well before completion of installation of APPR itself at Ft. Belvoir, Va. Subsequently it will be used in developing reactor designs. Employing 25-50 plate-type fuel elements, it will have a flux of 10^6 n/cm²/sec, a power level of 1 watt



Reactor News

Critical facilities in news. Three more private critical experiment facilities, or zero-power reactors, were announced last month, on the heels of two others (Nuclear Development Corp. of America, NU Feb. '56, p. 16; and Alco Products, Inc., see above). Babcock & Wilcox has received an AEC construction permit for a critical experiment facility for core tests, which it will build on the site of its fuel-element fabrication factory at Lynchburg, Va.; both are to be completed in April. Battelle Memorial Institute has completed a critical facility at its $3.5-million atomic energy center at Columbus, Ohio. Described as the first private installation of its kind available for direct research on atomic power plants, it will be used in propulsion as well as central-station studies. Finally, General Electric announced it will build not only a critical-experiment facility but a boiling-water reactor pilot plant as well at its new 1,585-acre atomic research lab site at Livermore, Calif. GE, which earlier set up temporary headquarters at San Jose for its 180-Mw dual-cycle boiling reactor project for Commonwealth Edison of Chicago (NU, Dec. '55, p. 16), this month said it would move its entire Atomic Power Equipment Department from Schenectady to San Jose, 20 miles south of the new lab site. The department is scheduled to be 500-strong by year's end.

Argonne tackles military package reactor problem. A smaller brother of Alco's 2-Mw APPR, the latest plant to be assigned Argonne National Laboratory for design and development would have only "a combined electrical- and heat-energy output of several hundred kw." Designated ALPR for Argonne Low-Power Reactor, it would be used for both power and space heating by military forces in remote areas. The reactor would be a heterogeneous direct-boiling type with water circulating through the core by natural convection. Goals are simplicity, ease of transportability and construction, reliability, ease of operation with a minimum of personnel, and no maintenance requirements for extended periods.

Six bidders for Latin reactors. American & Foreign Power Co. got six bids on its project to build three 10-Mw power reactors in as many Latin American countries. (The countries have not yet been chosen.) The bidders were Alco, AMF Atomics, GE, Westinghouse, North American Aviation, and Babcock & Wilcox jointly with Allis-Chalmers. Evaluation of the proposals is expected to take until end of March.

Yankee approved. After 10½ months and one rejection, AEC finally accepted Yankee Atomic Electric's proposal to build a 134-Mw nuclear power plant as basis for negotiation of a contract. Last to be accepted of the proposals under the first round of AEC's power demonstration program for financial and research aid to private reactor builders, the pressurized-water design had been beefed up from an original 100-Mw; even so, one known AEC objection had been that it was too much like the Shippingport PWR. In accepting the proposal, however, AEC said it had "determined that the plant would advance the art of reactor technology" by supplementing development at Shippingport. The plant is to be built at Rowe, Mass., 7 miles east of North Adams, and will serve all New England.

Bids on LSR asked. Westinghouse Electric Corp. issued specifications for building site facilities for the land-based Large Ship Reactor prototype at Arco, Idaho. Construction on the $1.8-million facilities will begin early next month. Western Steel Co. of Salt Lake City won the contract to build the hull-section housing the LSR with a $450,000 bid.

High-flux industrial test reactor planned. A. D. Little, Inc., Cambridge, Mass., consultants, are planning a 10^{15}n/cm²/sec testing reactor for New England. This flux would make it the world's most powerful research reactor. It would have 6-in. holes going all the way through the core, would be financed by selling test time in advance. GE designed, presumably would build it.

World News

Six new atomic commissions named. **Denmark** appointed a 24-member AEC to take over from a provisional body named last March; a 7-man working committee will handle day-to-day operations. Niels Bohr is expected to be chairman. In **Switzerland,** Otto Zipfel, former Labor Commissioner, was named representative of the Swiss Federal Council on all atomic energy matters; his functions will be those of an Atomic Energy Commissioner. He said his first task will be to coordinate work now being done by private industry with government guidance and financial aid. A committee to advise the government and to assure government-industry liaison is to be named. Behind the Iron Curtain, **Hungary** named an 11-man AEC headed by Deputy Premier Hidas. **Brazil's** new president Kubitschek named the former president of the National Development Bank, Glycon de Paiva Teixeira, head of the country's AEC. De Paiva is well known to U. S. mining officials, with whom he served on the joint Economic Development Commission in 1952–53 as minerals counselor. He has orders to install a 10-Mw nuclear power plant—Kubitschek is determined that his country be the first in Latin America to have atomic power—and to "encourage" free prospecting, mining, and production of U and Th, hitherto locked in the ground by law. **Japan's** Minister of State, Matsutaro Shoriki, heads his country's new AEC, which includes physics Nobel prizewinner Hideki Yukawa. And in **Germany,** a 25-man advisory AEC to guide Atomic Energy Minister F. J. Strauss was named. Its members, drawn from science and industry, are:

Hermann J. Abs, Süddeutsche Bank
Hans Boden, Allgemeine Elektrizitäts Gesellschaft
Leo Brandt, State Secretary, Düsseldorf
Richard Fischer, Cologne power plant director
Gerhard Geyer, Esso, Hamburg
Hans Godefroy, Allianz Insurance Co., Munich
Peter Josef Haas, board member DAG (German Employees Ass'n.)
Ulrich Haberland, Farbenfabriken Bayer, Leverkusen
Otto Hahn, president Max Planck Institute, Göttingen
Otto Haxel, Heidelberg University
Werner Heisenberg, Max Planck Institute, Göttingen
Ernst von Kämmerer, professor of law, Freiburg University
Karl Knott, Siemens-Schuckert Co., Erlangen
Friedrich Paneth, professor, Mainz
Alfred Petersen, board member, Metallgesellschaft, Frankfurt
Hermann Reusch, Oberhausen
Hans Reuter, Duisburg
Wolfgang Rietzler, professor, Bonn
Ludwig Rosenberg, German Trade Union Federation
Arnold Scheibe, professor of agriculture, Göttingen
H. Schöller, power plant engineer
Erhard Schubert, professor of medicine, Hamburg
Hermann Winkhaus, coal engineer, Düsseldorf
Karl Wiennacker, Farbwerke Höchst, Frankfurt
W. A. Menne (chairman), president German Chemical Industry Ass'n. and chairman of atomic energy committee of Bundesverband Deutsche Industrie (German Manufacturers' Assn.)

This group's nine subcommittees show its scope: mining; nuclear physics and chemistry; reactors; use of atomic energy in industry; traffic; medicine, biology and agriculture; civil defense and waste disposal; economic and financial; and legal.

Britain drops heavy water scheme. The U. K. has withdrawn from a joint British-New Zealand project to harness geothermal steam for the manufacture of D_2O. The hot springs at Wairakei were to have provided cheap electric power for the separation plant. However it was found equipment costs would run to $11.2-million, not $5.6-million as planned. It was pointed out the U. S. D_2O price of $28 per lb, one-fourth the estimated cost of production at Wairakei, had been announced since the U. K.'s original planning. AEC's report to Congress last month revealed the U. K. had bought 50 tons of U. S. D_2O, is our leading customer. New Zealand will continue the power end of the project.

Insurance study planned in Europe. A center for study of peaceful atomic energy risks has been set up in Paris by the European Insurance Committee.

Developments in Italy. Advices reaching NUCLEONICS from Rome report progress on four fronts. A 3-man mission headed by Prof. Giordani, chairman of Italy's National Committee for Nuclear Research (CNRN), has left Rome for the U. S. to negotiate purchase of a 1-Mw CP-5 type research reactor. The pile would be installed in Milan and operated by CISE—the Center for [Nuclear] Information, Studies and Experiments. The mission will also seek a loan of 20% enriched U^{235} fuel. Before leaving, Prof. Giordani had submitted a draft for an atomic energy law proposing that prospecting, mining, production, and use (except as fuel for power) of fissionable materials be a government monopoly. Meanwhile the structure of CISE was broadened: originally a private company founded in 1946 by Milan University physicists—thus antedating by six years the governmental CNRN, CISE has been reorganized as a half-State, half-privately-owned firm. Finally, CNRN's 1,000-Mev synchroton has entered the construction phase: Ansaldo-San Giorgio Co., Genoa, is making the magnet, and Compagnia Generale di Elettricità, Milan, the power supply; the lab buildings at Frascati are going up.

Euratom advances. The six nations of the European coal-steel pool have agreed to set up a similar supranational atomic pool, and Britain has ended her opposition to the plan. One day before the meeting of the foreign ministers of France, Italy, West Germany, Belgium, the Netherlands and Luxembourg at Brussels, the U. K. reportedly said she might "associate" herself with the pool, without joining it. President Eisenhower and Secretary of State Dulles gave assurances of U. S. support. The Euratom concept (NU, Dec. '55, p. 11) won out over a looser pool idea broached by a working group of OEEC (Organization for European Economic Cooperation), a 17-nation body in which governments cooperation without pooling any of their authority. The six foreign ministers declared their "determination to establish . . . forms of collaboration closer than those of the OEEC." No decision on the structure of the pool has been taken; the ministers meet again March 15.

Private atom industry advances in Britain. Associated Electrical Industries will build the U. K.'s first privately-owned and operated research reactor—a swimming-pool type, at Aldermaston Court, Berkshire. AEI (which includes Metropolitan Vickers and British Thomson-Houston) is, with John Thompson Ltd., one of Britain's four "study group" combines. Also, Rolls-Royce Ltd., active in light reactor development for aircraft propulsion, is completing a new nuclear engineering laboratory.

El Salvador getting radioisotope laboratory. $20,000 has been appropriated for the first such facility in Central America. It will be installed by the end of the year in Rosales Hospital in the capital. Four Salvadorean physicians who will man the lab will study in the U. S.

ROUNDUP

News in Brief

Forum Fair space demand heavy. Because of the demand for exhibition space at its second annual atomic trade fair in Chicago this September, the Atomic Industrial Forum has had to shift the site of the fair from the Morrison Hotel to the Navy Pier. This will make available 50,000 ft² of space, a threefold increase over last year. The Morrison remains site of the Forum's annual meeting Sept. 25–27; the fair will be open Sept. 24–28. This month, the Forum will hold a conference on "Public Relations for the Atomic Industry" at the Hotel Plaza in New York, March 19–20.

AEC opens "docket room." A document room where license applications and other unclassified records may be examined by the public has been opened by AEC. It is located on the ground floor of the headquarters annex at 1717 H St. NW in Washington, opposite the reception desk and outside the security area.

Radiation treatment for sewage? Nuclear Science and Engineering Corp. will investigate the possibility of using radiation to facilitate sewage treatment, under a contract with Hyperion Engineers, a joint firm of Los Angeles engineers retained by the city to carry out a $40-million sewer project. Even after treatment, sewage effluent has a bacteria count requiring it to be piped some 10 miles to sea to avoid beach pollution; irradiation may eliminate the need for such costly pipelines, it is hoped. One possible means of irradiating the effluent that NSEC is considering would be to run it through a reactor as coolant. NSEC will conduct the tests in its Pittsburgh laboratories and at established reactors on samples of city sewage.

Health physics program for Combustion. Nuclear Science and Engineering Corp. figured in another contract this month. It will set up a health physics and record-keeping system for Combustion Engineering's new Connecticut plant (NU, Jan. '56, p. 16). The contract provides for setting up radiation tolerance specifications, specifying instruments, carrying out measurements, and developing systems and procedures of fissionable material accountability.

Atom power on sale on West Coast. As some forecast last April, Southern California Edison Co. will be the first to have atom-generated electricity for sale in the West. AEC has authorized it to negotiate with Atomics International division of North American Aviation, for addition of a $1-million turbogenerator set to the Sodium Graphite Experiment AI is building. This second of the AEC's five reactors in its five-year development program will, when thus harnessed, yield about 7.5 Mw of electricity. SRE is expected to go critical early this summer; Edison hopes to be feeding current from the Santa Susana site 20 miles northwest of Los Angeles a few months later. It will not be firm power, but the experience to be gained, it's felt, makes the project worthwhile—for AI as well as Edison, particularly since AI's projected 75-Mw power reactor for Nebraska Consumers Public Power District is a tenfold scale-up of SRE.

Nuclear Standards group named. The American Standards Association has appointed Morehead Patterson, head of American Machine & Foundry Co., chairman of a 25-man planning committee on standardization in the nuclear field. ASA had been asked to name such a committee by a conference of 175 industry and government representatives (NU, Jan. '56, p. 10).

AMF Atomics enters British market. The American company and Mitchell Engineering Ltd., boilermakers of London, have completed plans for joint design and construction of nuclear power plants in the British Commonwealth. Walter Bedell Smith, head of AMF Atomics, called this the first international agreement of its kind in the atomic energy field and the first made by private U.S. industry to fulfill the President's Atoms-for-Peace program. The two companies' operations are complementary, AMF told NUCLEONICS; they see a mutual benefit in getting together in this field. AMF, seeking Commonwealth sales, gets a partner with contacts; Mitchell, looking ahead, avoids the almost complete dependence on the U. K. Atomic Energy Authority to which all other British companies in the field are constrained because of the shortage of trained personnel and the A.E.A.'s near-monopoly of it. Mitchell is not a member of any of the four "study-group" combines formed in England. AMF last month expanded outside the U. S. for the first time, with establishment of AMF Atomics (Canada) Ltd. (NU, Feb. '56, p. 89).

AEC opens its facilities to private industry. "In the interest of furthering private participation in the development of atomic energy for peaceful purposes," said AEC, it has decided to permit private firms and individuals to use its facilities and equipment for their own purposes. Prerequisites: the user must have necessary clearance, the work must not interfere with AEC work, private facilities must be "not reasonably available." Conditions: payment by the user to AEC of a charge based either on full recovery of costs of work to AEC, or on going commercial rates; compliance with AEC health, safety and security regulations; indemnification of AEC from claims involving private work; and "applicable patent provisions." Industry greeted the news largely with indifference, as not changing much. All AEC contractors and study groups had already had this possibility available.

International radiation group convening. The twin International Commissions on Radiological Protection and on Radiological Units will meet in Geneva in April. The two 12-man groups work interlockingly. Lauriston Taylor, head of the U. S. National Commission on Radiation Protection and a member of both world bodies, will head a delegation of U. S. scientists.

AEC turns over ore procurement chore. Lucius Pitkin Inc., New York metallurgical chemists, have been named AEC's representative to conduct its uranium and vanadium ore and concentrate procurement in the western U. S. The company will be responsible for buying, receiving, weighing, sampling, assaying and stockpiling. Pitkin will operate AEC's nine ore-buying stations in the West and the concentrate sampling plant and assaying laboratory at Grand Junction, Colo. The contract calls for cost-plus-fixed-fee.

Improving radioisotope distribution abroad. The U. S. has for some time been considering setting up istotope distribution centers overseas. Two U. S. teams may be sent abroad to look into the possibilities this spring. Another mission being planned is that which Marvin Fox, Brookhaven reactor chief, may undertake, to report on the best possible site for the nuclear research center the U. S. will give the Colombo Plan countries of Southeast Asia, and on what such a lab should contain.

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model 2603

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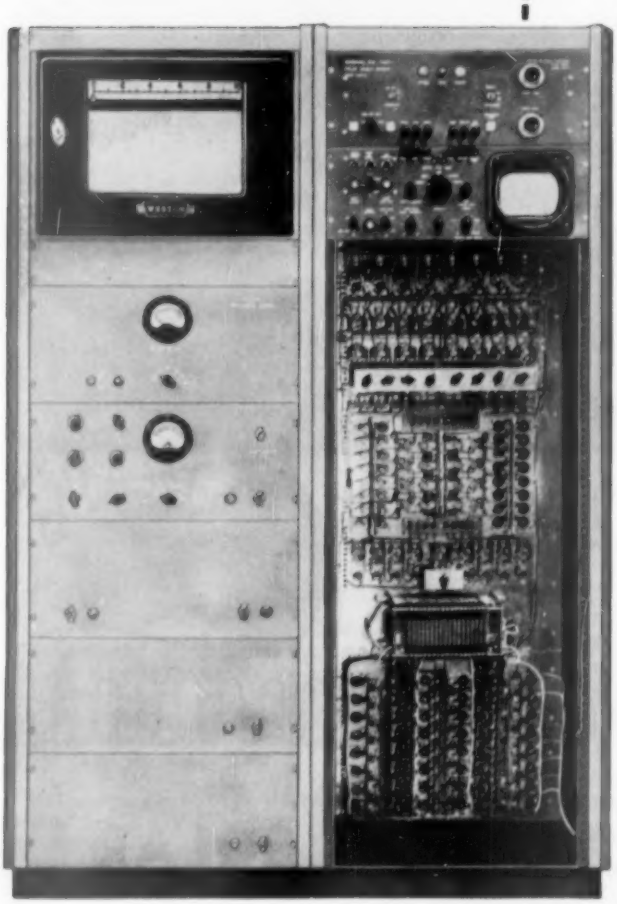

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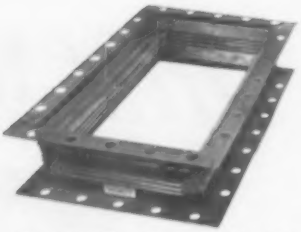
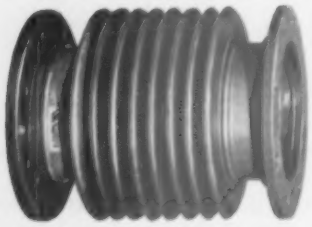
Sola-Flex bellows 



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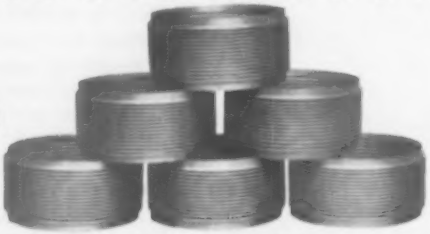
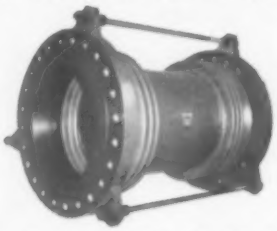
are made  in all sizes

and varieties 

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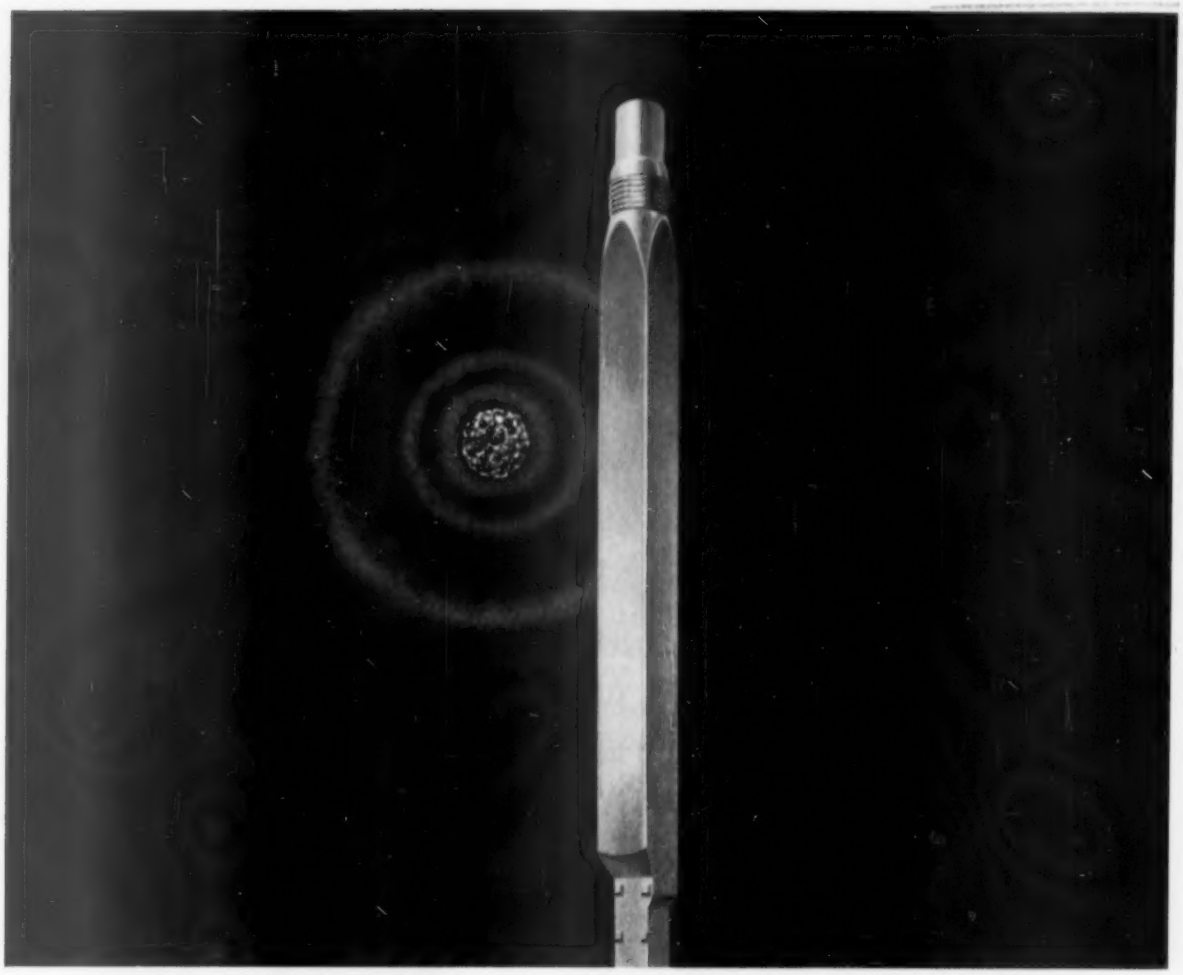

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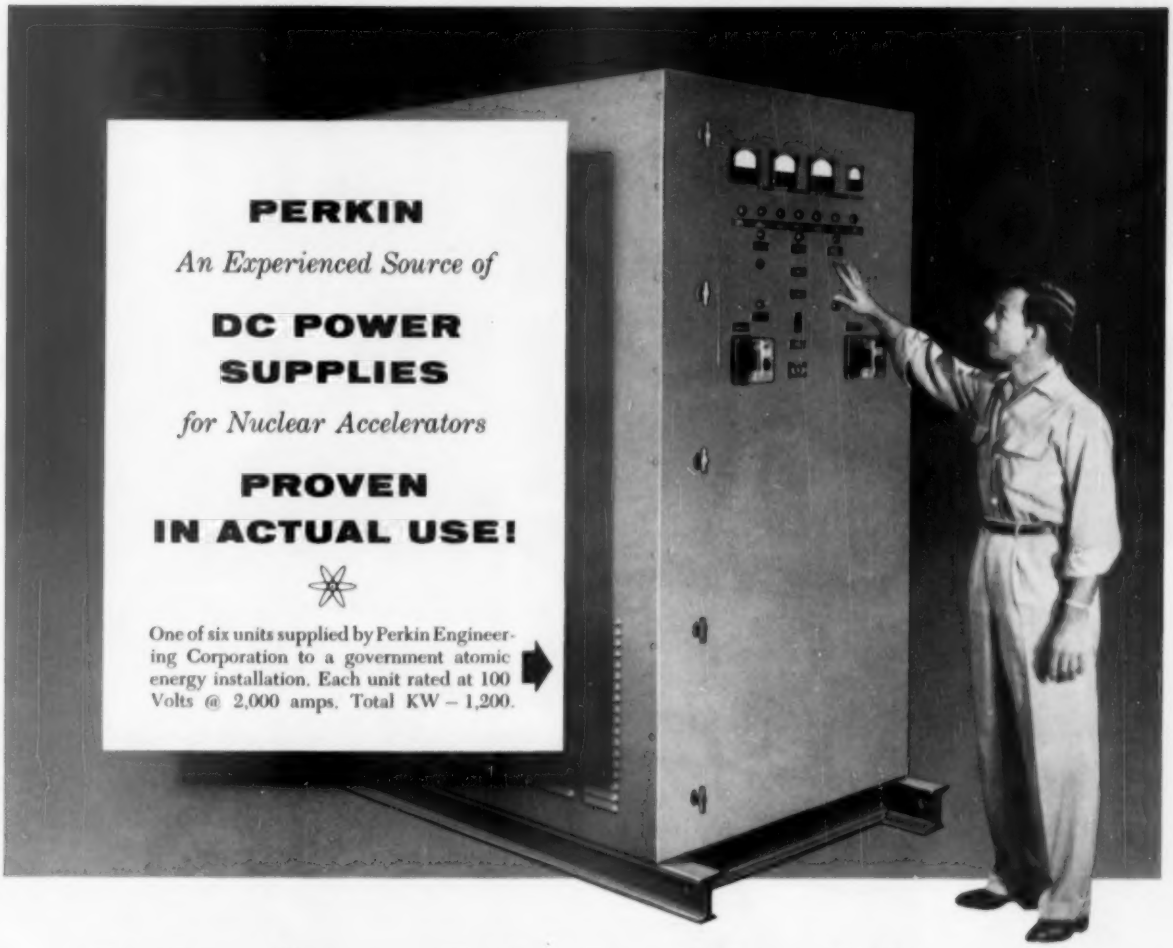
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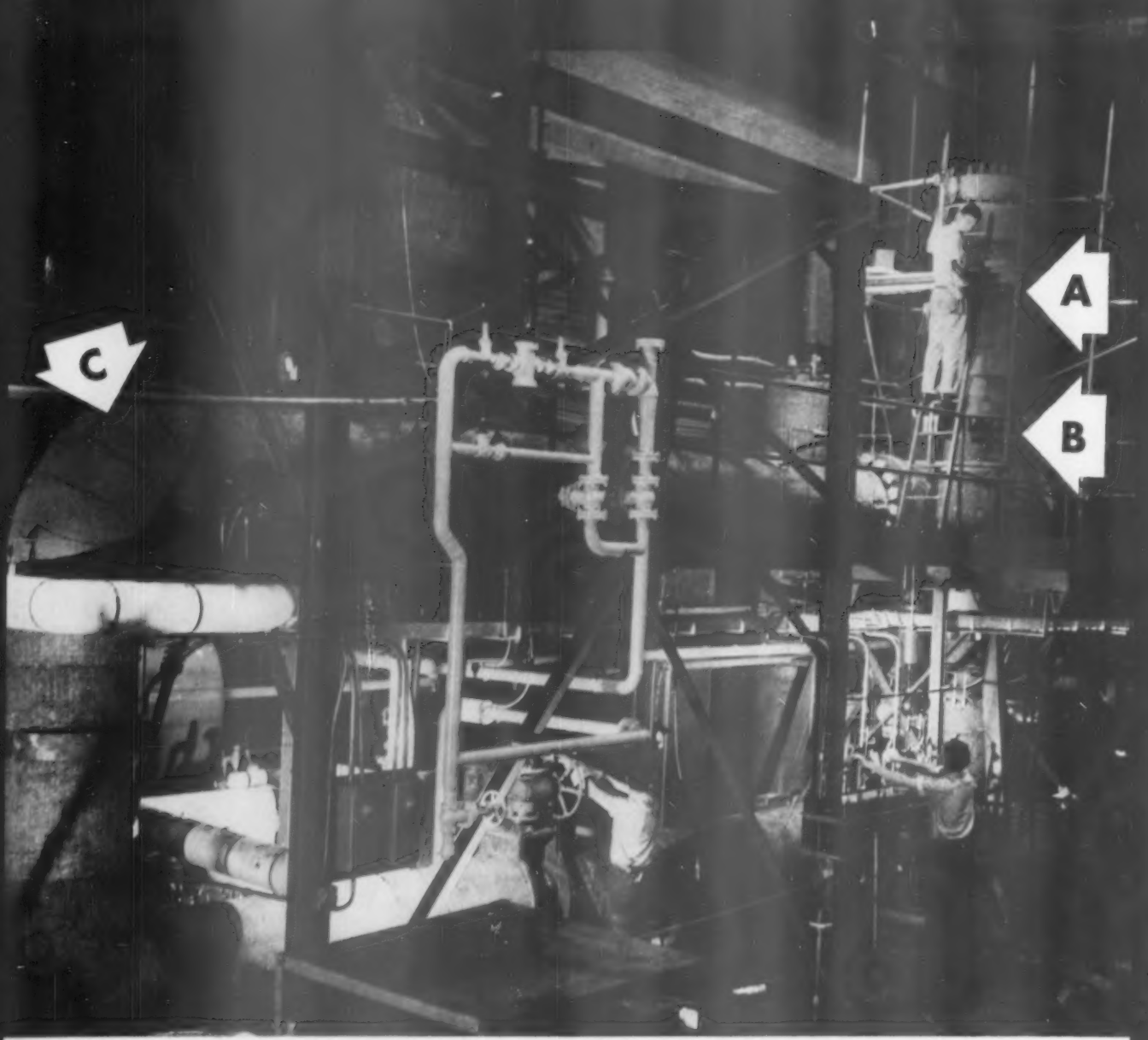

MOVING RADIOACTIVE WATER AT 650° F. This loop tests zero-leakage canned motor pumps at G.E.'s Medium Induction Motor plant. Motor (A) drives pump (B) to force the water through the pressurized loop (C). The pump bowl is one of the largest stainless-steel forgings ever made.

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Jerome D. Luntz, *Editor*

The McKinney Report

In 1946, when S. 1717, this country's first atomic energy legislation, was introduced in the U. S. Senate by Brien McMahon, the report accompanying the bill raised the fear that

> "the sudden introduction of certain devices utilizing the power released by nuclear fission might precipitate profound economic disorganization. Great industrial installations representing nationwide investments, employing many thousands of workers, might be rendered obsolete."

To forestall any such happening, Sec. 7b was included in the law, requiring the Atomic Energy Commission to evaluate and report on the "social, political, economic and international effects" of any proposed "practical" use of atomic energy before it could be approved.

Apparently, the 83rd Congress, in drastically overhauling the 1946 act in 1954, felt that the above fear was unwarranted. Nevertheless, last year, the Joint Committee on Atomic Energy set up a Panel on the Impact of the Peaceful Uses of Atomic Energy, under Robert McKinney, to produce, we feel, a 7b report.

The report that the McKinney panel submitted on Jan. 30 (see NU, Feb. '55, p. 9), if it makes no other point strongly, overwhelmingly bears out the implied contention of the 83rd Congress that atomic energy would not be a dislocating force. To the extent that the panel could foresee developments, it says that atomic energy will not cause mass unemployment, will not cause major shifts in industry. Rather, it says, power from the atom will be much needed by our economy and will take its place alongside other energy sources.

This is an important conclusion because it should serve to allay the fears that have existed in some quarters about competition from atomic energy. It should permit the fullest attention to be paid to rapid exploitation of the potential of the atom. And the report certainly verifies that there are many technological problems that lie ahead of the nuclear industry. In fact, because of this, the panel makes quite clear that it is still too early to assess the full impact of atomic energy.

Perhaps the most useful function of the report is to define major administrative, political and technical problems that face our atomic energy program. In the short period (ten months) in which the panel had to function and with the scope of questions it tackled, it is no surprise that it didn't penetrate very deeply into certain areas. In one vital area, insurance, Congressman Cole, architect of the present law, reflected this when he said, "Frankly, that was one of the angles of the atomic problem that I hoped and expected the panel would undertake a study of. Their findings on that in that respect leave me right about in the same position I was in when we started out. It was of no help at all."

However, the panel did do a lot of stirring up of thinking among AEC and industry personnel. In fact, it performed a function that the Joint Committee might well have carried out itself and certainly should get into in the future. The volume of background material that the panel generated should provide an excellent starting point for future analyses of nuclear activities.

In three specific areas—international, secrecy and administration—the panel had comments that have evoked mixed reactions. On the international side, the McKinney group recognizes the immediate interest in nuclear power abroad and says that 100,000,000 kw of nuclear capacity may be installed outside the U. S. by 1980, and that U. S. industry may have a $30-billion foreign market to shoot at. But for our companies to be able to tap this, the U. S. government has got to stop spinning its wheels and come up with an imaginative policy that would make it conducive for foreign countries to do business with us.

Then, the McKinney panel turned right around, threw up its hands at the prospect of international control of fissionable material being achieved in the near future, and recommended a conservative policy wherein foreign recipients of U. S. fuel would be required to return it to the U. S. for reprocessing, a policy that is sure to retard our attempts to tap the foreign market. This recommendation was in direct opposition to one made by one of the panel's seminar study groups. And it also flouts the growing feeling that, with many countries soon to have the capability of producing their own plutonium, attempts to control or oversee worldwide plutonium production are not practical.

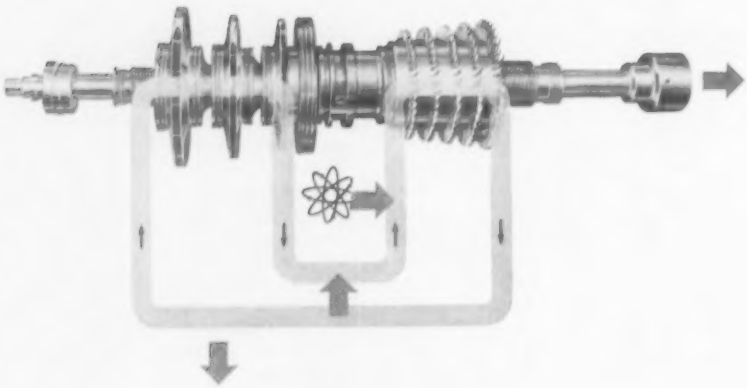
On secrecy, although without getting very deeply into philosophical justification of it, the panel recommended complete declassification of reactor technology. This is wise and needy of immediate implementation to forestall the possible major pitfalls of the burgeoning access permit program, under which there is being set up a sizeable bureaucracy for spoonfeeding confidential information to industry. Strangely, on secrecy of controlled thermonuclear power work, the panel accepted AEC's controversial argument for classification—that neutrons generated can produce fissionable material—and merely suggested that the secret data be more widely disseminated.

Left substantially untouched by the panel is a question that perhaps affects all other aspects of our atomic energy program—what changes, if any, should be made in future governmental atomic energy structure. With atomic energy having entered a new era, it appears to us that there is a very serious question whether a single five-man commission can continue to bring the energy and imagination to bear on such very diverse matters as developing our military atomic arsenal, regulating a new industry, and spurring the development of the peaceful atom. AEC recognizes its primary function as military atomic energy. Can it also bring to bear independent vision on the non-military side? This is a question that needs an answer quickly.

The McKinney panel can have served a useful purpose if the needling job it started is followed through. It is the responsibility of the Joint Committee on Atomic Energy to see that this is done.

ESCHER WYSS

the closed-cycle gas turbine power plant for efficient use of nuclear energy



The closed cycle gas turbine power plant using a fossil heat source has been under intensive development by the firm of Escher Wyss Ltd. of Zurich, Switzerland and their licensees for a number of years. Plants built according to these principles are in operation in many parts of the world. Use of this power plant cycle with a nuclear heat source makes possible use of fission energy at a high temperature level, resulting in a power plant of high efficiency. Use of an inert gas as a power plant working fluid, heated directly in a nuclear reactor, removes the problem of chemical attack on reactor or power plant components in the transport of heat to the point of conversion into mechanical energy.

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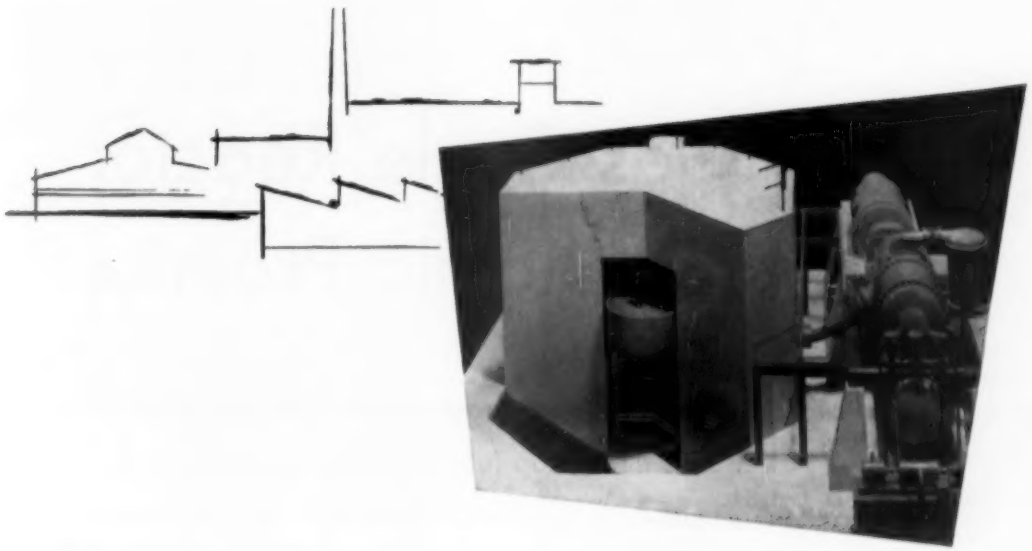


A Special Report

Gas-Cycle Reactors For Power

U. S. interest in gas-cooled power reactors is re-awakening after lying dormant for nearly a decade. Triggered by gas-turbine developments that give hope for efficient small units, the enthusiasm is spurred on by the promise of cheaper reprocessing and fewer material and overheating problems.

A gas-cooled reactor for civilian power was proposed by Manhattan District personnel at the University of Chicago in 1944. A high-temperature unit, its fuel and moderator would have been made of ceramics. A short-lived program for developing and constructing this design—known as the Daniels Pile—was launched at Oak Ridge, but it was stopped in 1947. In retrospect, AEC officials who had been associated with the project say it died because it was premature—the project was overly ambitious because the technology was not available at that time and too many things had to be done at once. Many today feel that the project should not have been dropped; they regret particularly that its early discontinuance left an unwarranted stain on the gas-cooled approach.

However, the wheel has come almost full circle, and thanks not only to its champions here, but also to experience abroad, particularly in France and Britain, gas cooling again has become an important prospect for certain applications. In this special report, NUCLEONICS presents the nucleus of current U. S. thinking on gas reactors.

Starting on the next page, the original proponent of gas-cooled reactors, Farrington Daniels, calls for a reappraisal of their merits and for construction of a 5-Mw plant using helium and a gas turbine. An analysis of other gas-reactor concepts is presented on page 42.

Small Gas-Cycle Reactor Offers Economic Promise

Advances in gas turbines and a realization of the importance of small power units and cheap fuel reprocessing call for a re-examination of gas-cycle reactors. Operation of a helium-cooled reactor, with graphite as moderator and fuel container, would demonstrate the cycle's flexibility and economy

By FARRINGTON DANIELS
Department of Chemistry
University of Wisconsin
Madison, Wisconsin

DEMAND FOR SMALL power reactors has been focussed since the United Nations Conference on the Peaceful Uses of Atomic Energy. The nonindustrialized nations, particularly, need small units (5–50 Mw) of low initial cost and easy transportability. Much of the American development of nuclear power stations has stressed large units using standard practice with high-pressure water and metals machined to close tolerances. Nuclear fuels offer new possibilities—it is not necessary to cling to traditional techniques based on experience with combustion fuels.

It may be possible to build a simpler and cheaper power reactor in which inexpensive fuel reprocessing of the partially spent fuel is stressed and the dangers of overheating are minimized. The design suggested here is similar to that proposed a decade ago, with fuel and moderator made of ceramics, operating at high temperatures with gas cooling (*1*). Unfortunately, the first engineering development of a nuclear power plant was cancelled in 1947 before construction plans could be completed (*2*). A revised plan was proposed in 1950 (*3*). Advances in gas turbines and a realization of the importance of small units and cheap fuel reprocessing call for a re-examination at this time (*4*).

Gas turbines offer much promise for the future; even now they have advantages of small size and flexibility in use. But, to heat the gas above 1,200° F so as to operate a gas turbine effectively requires that the reactor be so hot that occurrence of accidental hotter spots might melt iron, nickel, zirconium, beryllium, and other metals usually considered for reactors. Most designs presented to date would not permit practical operation of a gas turbine.

But it is not necessary to have metals in the reactor. They can be replaced with ceramics. Conventional heat engines require an excess of oxygen for the combustion of fuel and thus graphite and molybdenum and certain other high-melting materials cannot be used. But oxygen is not needed for a nuclear reactor.

It is proposed then to dispense with metal fuel units and metal canning in the interior of the reactor and to use graphite, cooled by helium. The graphite moderator and the enriched-uranium-carbide and graphite of the fuel rods can go to 3,600° F and higher without any ill effects.

Most of the radioactivity will be confined within the graphite fuel units, but there will be some diffusion of volatile fission products. The extent of this radioactive contamination is difficult to predict on the basis of calculations or laboratory experiments. Thus, it will be necessary in the first reactor to include a heat exchanger so as to prevent possible contamination of the turbine; and to include in the reactor circuit a small by-pass with gas purification equipment.

Plant Layout

As shown in Fig. 1, the reactor coolant circuit and the power system are in separate compartments and are separated by a gastight heat exchanger. Figure 2 shows temperatures, pressures, and flow of gases.

The stainless-steel pressure shell enclosing the reactor is 10 ft in diameter and 15 ft high; it has tubes protruding 9 ft above the top for control-rod-clearance. It is surrounded by 5 ft of concrete for shielding. The heat exchanger is 5 ft in diameter and 25 ft tall; it is surrounded by concrete 2 ft thick. This concrete enclosing wall is 30 ft high, 25 ft wide, and 35 ft long in its outside dimensions.

The turbine room, 20 ft high, 30 ft wide and 35 ft long, has concrete walls 1–2 ft thick. Most of the installation is underground. About 60,000 ft^3 of concrete is involved. The inside of all concrete walls is faced with thin stainless steel and provided with drains to aid in decontamination.

The expansion chamber connects to the reactor through a 2½-ft duct and pressure diaphragm of thin metal that will rupture if the helium pressure exceeds 225 psi. Its volume is 8,400 ft^3, which would reduce the 560 ft^3 of helium at 15 atm to a pressure of 1 atm above the atmospheric pressure already in the expansion chamber. The expansion chamber can be used also in case of a leak in the pressurized-helium circuit.

A hemicylindrical metal roof of the Quonset type is placed over the whole concrete housing to contain still further any radioactive gas or dust in case of leakage or accident.

Reactor

The reactor core is 6 ft in diameter and 5.5 ft tall. It is composed of boron-free graphite blocks arranged vertically. The blocks are supported on a molybdenum grid, held up by molybdenum or beryllium-oxide pillars. The lower ends of the blocks in the second and third tiers have square tapers that fit into square recessions, thus keeping the blocks vertically aligned.

Figure 3 shows one of the moderator blocks. Since graphite is an excellent conductor of heat, and at high temperatures some of the heat is carried by radiation, contact surfaces between graphite blocks do not decrease the heat flow seriously. Figure 4 shows the loading pattern for one-fourth of the reactor.

The 1.5-ft-thick graphite reflector surrounding the core is made with blocks 3¾ × 3¾ in. The ½-in. holes through the top and bottom reflectors are continuous with those in the reactor. There are additional ½-in. vertical holes through the lateral reflector to remove heat produced by $Th\text{-}U^{233}$ breeding that takes place in thorium carbide placed in the outer reflector. The reactor uses 156 ft^3 (9 tons) of graphite; the reflector uses 384 ft^3 (23 tons). There is a 6-in. ring of insulating brick between the reflector and the pressure shell.

The thick pressure shell can withstand considerably more than the 225-psi reactor pressure. It is cooled on the outside by circulating air.

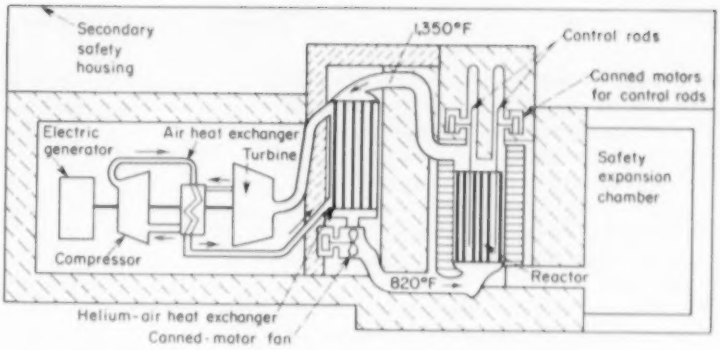


FIG. 1. Profile of the 5-Mw closed-cycle plant. Reactor, which produces 20-Mw heat, has graphite moderator and uses fuel rods of 10%-enriched UC_2. Entire 225-psi helium circuit for reactor is gastight. Heat in He goes to 400-psi air or nitrogen via a gastight heat exchanger that separates the two circuits. Concrete roof and underground walls serve as shield. Expansion chamber and safety housing can contain any radioactive gas or dust that might be released in an accident. Boron-containing molybdenum control rods are moved vertically by canned motors

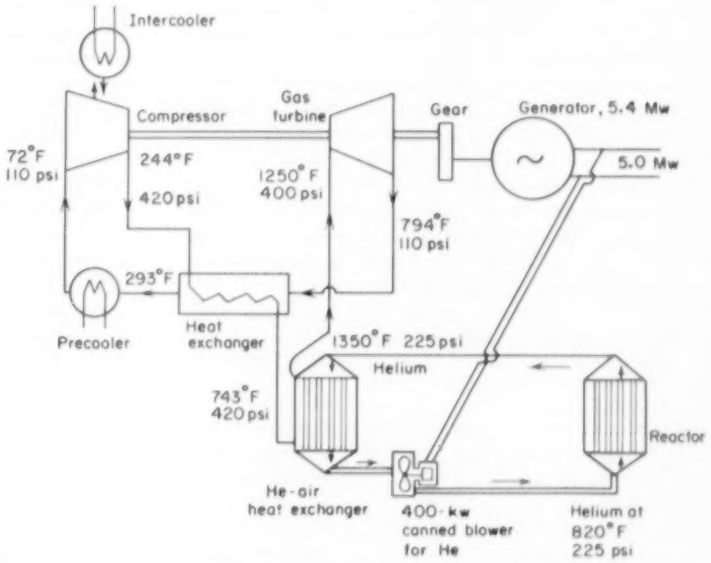


FIG. 2. Flow diagram for the 5-Mw gas-cooled plant shows a plant efficiency of 25%. Coolant circulation by canned-motor blower uses less than 10% of plant output. Air flow in closed turbine circuit is 470,000 lb/hr. He flow in closed reactor circuit is 103,000 lb/hr. Boron-containing molybdenum control rods are moved vertically by canned motors

Fuel Units

Uranium carbide, UC_2, is chosen as the nuclear fuel because it can be heated to temperatures above 3,600° F in contact with graphite and helium without appreciable reaction, vaporization, or formation of gaseous products. After removal from the reactor, it oxidizes easily in 2,000° F air to give uranium oxides, which dissolve readily in nitric acid to give uranyl nitrate without evolving gases. The uranyl

Design Justification

There are good reasons for using a heat exchanger and helium in this plant. Later units might not have the exchanger and nitrogen might replace the helium.

The 5-Mw turbine can be ordered now, but larger sizes will come along later to reduce investment costs. The gas turbine is favored over the steam turbine because it is more flexible and efficient and offers the possibility of a direct cycle that would use the reactor coolant to drive the turbine directly.

Heat exchanger. *Power reactors should be designed so that there is no leakage of radioactive gases or dust into the atmosphere. Apparently, leakage from high-pressure gas turbines varies considerably. But it is likely that there will be some leakage of 400-psi air from the turbine to the atmosphere. It cannot be permitted to carry radioactive contaminants. Thus, although the heat exchanger between the reactor and the gas turbine reduces efficiency and adds about $100,000 to the cost, it is considered necessary so as to prevent any possible danger from radioactivity. The heat exchanger has no moving parts to fail and the canned motor can be removed and replaced by remote control.*

Since fission products will escape from the graphite cartridges only to a slight degree and they will be removed continuously by the charcoal trap as rapidly as they are released, it probably will be possible in later models to eliminate the heat exchanger. But until the system has been tested under actual working conditions, it would not be safe to allow the coolant gases to go into the turbine circuit. Also, repairs to the turbine would be difficult if it should become contaminated.

Helium. *Air cannot be used in high-temperature graphite reactors because the graphite and the molybdenum control rods would oxidize. Although helium has not yet been used in gas turbines, a helium turbine has been designed and it has many advantages.*

The gas turbine and its compressor can be used with nitrogen as well as air, and nitrogen is inert toward graphite. But nitrogen will react with molybdenum or tungsten control rods. Other metals will not safely withstand the peak temperature in the reactor, and ceramic control rods have not yet been developed to withstand the necessary mechanical strains. When ceramic control rods are developed that operate infallibly at 3,000° F it will be possible to use nitrogen.

Another argument for helium gas as a coolant is that it has an extremely low cross section for neutron absorption and it forms no radioactive product. Nitrogen at 225 psi would absorb some neutrons and produce some radioactive carbon in the coolant circuit.

Size. *Strong arguments can be advanced for building the first power plant for 10 Mw instead of 5. The cost of the turbine is, of course, greater; but the housing space for turbine and reactor would not be much larger. The graphite reactor can take care of the extra heat without appreciable alterations. But the 5-Mw turbine is ready to order, while the 10-Mw unit requires a longer delivery time. The entire design calls for pioneering and it probably would be wiser to build the first unit on the smaller basis. Certainly, the second unit should go to 10 Mw, and thereby reduce the cost per kwh.*

Steam vs. gas. *The circulating helium in the reactor circuit could be passed through a boiler to produce high-pressure steam and operate a steam turbine. Thus, one could go at once to large (100-Mw) reactors with standard equipment. But gas turbines are smaller and more flexible than equivalent boilers and steam turbines, and they probably are more efficient in small sizes.*

nitrate is a convenient material from which to separate the fission products and to regenerate the carbide.

Preparation. The enriched-uranium carbide, containing 10% U^{235}, is prepared by heating enriched-uranyl nitrate to red heat in air to obtain U_3O_8. The U_3O_8 then is mixed with an excess of reactor-grade powdered graphite and heated to 3,600° F in a nonoxidizing atmosphere. The amount of graphite added is such that the resulting UC_2 and graphite is just sufficient to fill the 22,000 3-in. fuel cartridges for the 1,000 fuel channels. This quantity of uranium carbide and graphite should contain 13.7 kg U^{235}.

In a laboratory experiment, a 1:5 mixture of U_3O_8 and graphite was heated in graphite containers in a graphite electrical-resistance furnace through which a stream of argon was passing. After 2 hr at 2,700° F and a few minutes at 3,600° F, the mixture was cooled in argon and analyzed. X-ray analysis indicated UC_2 and graphite, without appreciable X-ray patterns of U_3O_8, UO_2, or U.

Assembly. The fuel units might be prepared by mixing UC_2 and graphite powders with a little stearic acid and extruding them as cylindrical rods. Each rod is inserted in the hollow center of a graphite cartridge, which is then plugged with small graphite stoppers. The National Carbon Co. has developed impervious graphite cylindrical tubes into which end plugs are fastened tightly with graphitic sealing material. They are probably sufficiently impermeable to gases to confine most of the fission products. Most of the easily volatile fission products are short-lived and they should be confined in the closed cartridges long enough to decay considerably. The impermeable graphite tubes come in 6-in. lengths, but the 3-in. lengths are chosen so as to minimize danger that the cartridges might stick in the fuel channels because of expansion due to radiation damage. The reactor's high temperatures will tend to anneal out the radiation damage.

Other methods. In an alternative method of filling, the uranium carbide, graphite, and stearic acid are pelletized by remote control in a Stokes pellet machine and are dropped into the cartridges as shown in Fig. 5. In still another method, the cartridges are plugged at one end and filled with uranium oxide and graphite powder thoroughly mixed and rammed in tightly. The cartridges are heated to 3,600° F by passing a heavy current of electricity through them while they are buried under carbon flour to prevent oxidation. The heating releases carbon monoxide and produces uranium carbide, UC_2 (*5, 6*). After cooling in the absence of air, the second graphite plug is inserted and sealed.

Loading. The fuel cartridges are blown into their channels with com-

pressed helium through a centrally located, rotating curved delivery tube. The cartridges are introduced through a loading room beneath the reactor. A constriction at the reactor top holds them in place; a sliding molybdenum gate under each fuel channel supports the cartridges until they are discharged.

It is assumed that 10 kg of U^{235} will make the reactor more than critical; the extra 3.7 kg U^{235} is included to replace that consumed in 6 months operation at 20 Mw heat (5 Mw electricity). Accordingly, 13.7 kg of U^{235} is placed in the reactor together with adequate poisoning rods of molybdenum containing boron carbide. Because there is no highly neutron-absorbing material in the reactor, considerably less than 10 kg of U^{235} probably will be sufficient for criticality. It is assumed that the uranium probably will be enriched to 10% U^{235}, that 137 kg will be the total weight of uranium, and that 150 kg will be the weight of UC_2 used. This 150 kg of UC_2 together with 65 kg of graphite powder will be contained in the fuel cartridges. If 20% U^{235} is used, UC_2 weight is halved.

Control Rods

The 15-ft-long regulating rods are of molybdenum and contain boron or boron carbide. Each control rod is operated through a rack-and-pinion mechanism by a canned motor. When raised, the rods move up into closed tubes protruding 9 ft above the pressure shell. These tubes and the housing for the canned motors are all welded tightly to the pressure shell, which contains the 225-psi helium. No leakage can be tolerated.

Safety rods, similarly of molybdenum and boron or B_4C, are suspended in other vertical protruding tubes. The rods fall into the core if a small stainless-steel wire melts from He overheating or if the He pressure falls.

Molybdenum is used because it is one of the few metals that have a very high melting point and is not excessively expensive ($5/lb). It cannot be used at high temperatures in the presence of either oxygen or nitrogen, but it is perfectly stable in helium. In fact, the need for infallible and unbreakable metal control rods that will withstand temperatures of over 3,000° F dictates the use of molybdenum (m.p. = 4,750° F), tungsten (6,100° F), titanium (3,275° F), or a similar metal. These metals require the use of helium.

FIG. 3. Part of one of the graphite moderator blocks, which are $3\frac{3}{4} \times 3\frac{3}{4}$ in. in cross section and have a density of 1.9 gm/cm³. Fuel cartridges are in four of the $\frac{1}{2}$-in.-diameter holes (shaded) in each block; other 12 holes channel coolant. Standard length of blocks is 45 in.

Steel in nitrogen would be satisfactory up to 1,800° F.

Reactor Cooling

The reactor is cooled by 225-psi helium gas. At this pressure, helium has nearly the same heat-transfer properties as air at 400 psi, which is the operating pressure for the gas turbine.

The helium, in passing through the reactor's 3,000 cooling holes (each 8.5-ft long), removes heat from the central 5.5-ft portion where the heat is generated. The surface area of each cooling hole in the core is 0.72 ft² (2,160 ft² is total for the 3,000 channels). The surface temperature of the reactor cooling holes will vary from the helium inlet temperature of 820° F to 1,500–1,800° F. No difficulty will be experienced if the surface temperature goes much higher than this (over 3,600° F), but the temperature of the heat exchanger cannot be allowed to rise too high. Thus, a gas supply shunt will dilute the hot helium with colder helium if necessary. The colder helium can be shunted from the inlet around the reactor, or it can be passed through a water-cooled heat exchanger. The author has had experience in handling gases at temperatures up to 3,800° F in equipment of about the same size as the reactor described here (7).

Blower. The blower for circulating helium in the closed system will be operated by a canned motor, with long bearings removed from the high temperature region and radioactivity. The motor housing chamber is cooled. Allis-Chalmers Manufacturing Co., Westinghouse Electric Corp., and others have experience in designing and constructing large canned motors. The blower and motor are housed in such a way that they can be removed and replaced by remote control in case of failure.

Ducts. The 2.5-ft-diameter ducts leading the helium to the heat exchanger are of type-316 or -347 stainless steel lined with firebrick. The helium volume is estimated as 565 ft³, broken down as follows: 3,000 $\frac{1}{2}$-in. holes 8.5 ft long = 37 ft³, top and bottom of reactor shell = 325 ft³, ducts = 100 ft³, heat exchanger = 103 ft³. This volume of helium is equivalent to 8,475 ft³ measured at 1 atm; less than half as much if measured at room temperature. Since the whole circuit is gastight, there will be practically no make-up helium.

Bypass. Some xenon and short-lived volatile fission products will probably escape and gases will be driven out of the graphite when it is heated. Thus, it is necessary to circulate continuously a small fraction of the helium through a cyclone separator and through activated charcoal in a cold trap to remove all material other than helium. Since the fission products (mixed with graphite and UC_2) are enclosed in graphite tubes in channels through which helium does not circulate, fission-product particles are not likely to be picked up in the helium.

Heat Exchanger

The simple standard-type heat exchanger is a stainless-steel shell 5 ft in diameter and 25 ft long with 3,000 parallel $\frac{1}{2}$-in. tubes of stainless steel. Helium at 225 psi and 1,350° F enters the small tubes and leaves at 820° F. In the turbine circuit, 420-psi 743° F air enters the heat exchanger, is heated by contact with the helium tubes, and leaves at 1,250° F for entrance to the turbine.

The heat-exchanger shell must withstand 420 psi at 1,350° F; the $\frac{1}{2}$-in. tubes must withstand 420 psi outside and 225 psi inside at 1,350° F. No pinhole leak can be tolerated between the reactor-helium circuit and the

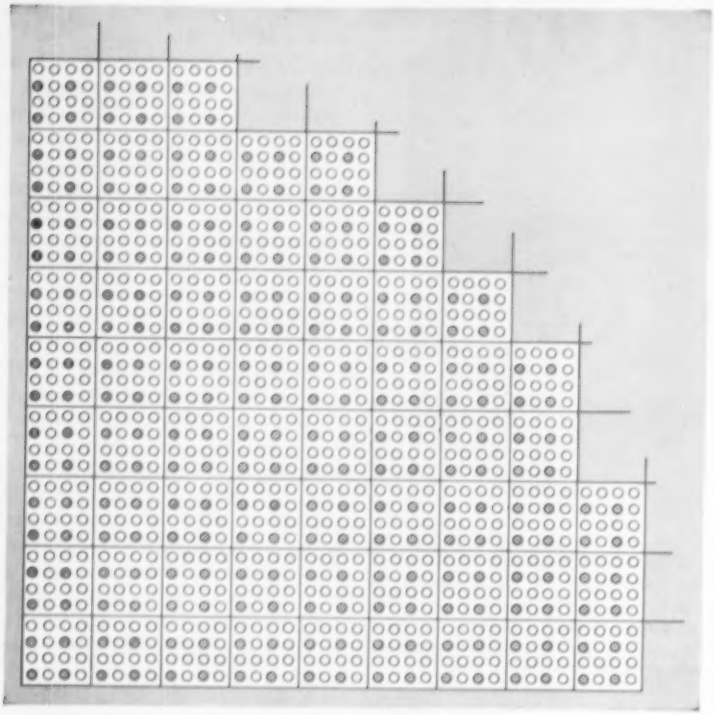


FIG. 4. Assembly of graphite blocks for one-fourth of the reactor. Each fuel-rod hole is surrounded by eight coolant channels. Complete reactor has 1,024 fuel channels and 3,072 helium channels; latters' voids make up 14.4% of reactor volume. Since equivalent of six blocks is needed for control rods, calculations assume 1,000 fuel channels and 3,000 cooling channels. These are contained in 256 tiers of blocks

turbine-air circuit because of the possibility of radioactive contamination.

The volume of the 3,000 tubes is about 100 ft³ and their total surface area is about 10,000 ft². The heat exchanger probably can be reduced considerably in size, perhaps to half.

Gas Turbine

The Escher-Wyss Co. of Zurich, Switzerland, makes a closed-cycle 2-Mw gas turbine that has an efficiency of 30%. It is especially suitable for the power reactor described here. The American Turbine Co. of New York are licensors and the Nordberg Engineering Co. of Milwaukee and Westinghouse Corp. are licensed to manufacture the equipment.

The standard gas turbine operates with a standard air heater heated by combustion fuel, but for the power reactor described here it would be heated by helium from the reactor. Since the 2-Mw turbine is too small for the proposed unit, a larger 5-Mw model is needed. Such a model is fully designed and ready for production. It can be delivered within 18 months. A still larger model, of 10–15 Mw, has been designed and probably could be delivered within two years. The turbine and accessories can be regarded as tested, off-the-shelf, stock machinery. They will be accessible for repairs because the heat exchanger protects them from any radioactive contamination.

The turbine and compressor weigh 31 tons; the heat exchanger for air in the turbine circuit weighs 52 tons; the electric generator weighs 23 tons. The whole power system, up to the helium-air heat exchanger and including the dynamo, weighs 106 tons. Over-all length is 33 ft and width is 12 ft.

Costs

An accurate statement of costs is impossible in a preliminary design of this type. Some of the equipment, materials, and services are listed here for reference in making firmer estimates: gas turbine with 5-Mw dynamo and accessories; 32 tons of boron-free graphite; 60,000 ft³ of concrete; heat exchanger; 7.4 kg U^{235} (10% enrichment) for 1 yr operation at 25% conversion of heat to electricity (twice the 3.7 kg/6 mos); 6% annual interest on 10 kg U^{235} required to make reactor critical; blower and 400-kw canned motor; steel enclosing shell; control rods, motors, controls; secondary roof; instrumentation; gas purification equipment; chemical processing equipment; design and engineering; construction; and operation for 1 yr. Total cost probably will be about $2-million.

It is assumed that: (a) 10 kg of U^{235} in the form of 10%-enriched UC_2 will be more than sufficient to make the reactor critical; (b) this nuclear fuel can be obtained on loan and the unused portion returned for credit.

Assuming continuous operation at 5 Mw for a year, 43.8×10^6 kwh of electricity would be produced. The cost per kwh can be calculated. The fuel cost can be reduced considerably by the conversion of Th to U^{233} or the conversion of U^{238} to Pu^{239}.

The capital charges are high for small power units. If the first 5-Mw reactor costs $2-million, capital cost will be $400/kw. For a reactor producing 10 Mw of electricity and costing $3-million, the investment would be $300/kw. Actual costs will depend on the price of the equipment, amortization rate, annual operating cost, and on the price of enriched uranium.

Operation

The nuclear constants for uranium and graphite are so well known that it probably will be possible to build the full-sized reactor with the graphite blocks in their final arrangement. Considerable adjustment of the fuel loading can be made by changing the ratio of graphite to uranium carbide in the

FIG. 5. Cutaway of fuel cartridge shows a unit similar to those for this reactor. Fuel, which might be pellets as shown here, fits in hollow center of a 3-in.-long 12-mm-diameter graphite cartridge that has a 6-mm bore; cartridge is plugged at ends by small graphite stoppers. Other fuel fillers might be: (a) single pieces of $\frac{1}{4}$-in. diameter and $2\frac{3}{4}$-in. length, or (b) UC_2 and graphite powder

fuel, or by changing the enrichment.

After running first at low levels the reactor should be operated at 20-Mw heat for 6 months. It might be possible to drop out the partially-spent fuel cartridges containing the UC_2 and graphite pellets, and to reload with fresh cartridges while the reactor is in operation. However, in view of experience with the first power reactor design in 1946 and 1947 (*2*), where much effort was expended in trying to design a reloading mechanism that would function under gas pressure, it will be better to assume that the reactor will be shut down briefly for reloading. At such times, the excess helium will be pumped into reservoir tanks to reduce reactor pressure to atmospheric.

Uniformity of temperature throughout the reactor can be achieved by increasing the UC_2-to-graphite ratio in the outer rings of fuel and decreasing it in the central part of the reactor, or by leaving out some of the fuel cartridges in the central part and introducing them later, when it becomes necessary to override fission-product poisons.

The burnup of U^{235} is calculated on the basis that fission of 1 gm of U^{235} yields 1 Mwd of heat. Thus, 6-month operation at 20 Mw heat will require 3.7 kg U^{235}. Some of the extra neutrons will be used for converting thorium into U^{233} and a few will produce plutonium from the U^{238}. The thorium carbide pellets are in graphite cartridges packed in $3\frac{1}{2}$-in. vertical holes in the graphite reflector. Since there is no canning material to absorb neutrons and no neutron absorption by the coolant, neutron economy is very good. This affords a better opportunity for conversion and breeding than exists in many other reactors.

The suggested 6-month period of operation is purely arbitrary. The length of operation before shutdown will depend on the fission-product poisoning and not on dimension or property changes due to radiation damage. There are no close dimensional tolerances and the disintegration of fuel units in the graphite cartridges will do no harm. Part of the radiation damage to the graphite will be annealed out at the high temperatures.

The fuel pellets of UC_2 and graphite might disintegrate, but the resulting powder is contained in the graphite cartridges and the heat produced in it by fission is conducted and radiated to the cartridge and thence to the helium-cooled moderator block. The heat conductance of graphite is as good as that of many metals. The temperature of the uranium carbide-graphite fuel might be much higher than the surface of the cooling channels, but no harm will be done.

The helium must be purified during operation, particularly at first. Moisture, air and hydrocarbons will be driven out of the graphite on heating and there may be carbon dioxide, dust particles, and radioactive xenon and other fission products. A dust-collector and a gas trap containing adsorptive charcoal at liquid-air temperatures will be operated continuously in a small bypass to remove the impurities and to allow any fission products to decay. The helium is circulated in a closed system and only a very small fraction of the total stream is shunted through the purifying system.

An electrically-heated, replaceable, molybdenum or titanium wire will serve to remove any oxygen from the helium and to indicate by an increasing electrical resistance if any appreciable amount of oxygen is getting in.

Safety

No liquid-to-vapor phase changes are possible with the materials used in this reactor. The 225-psi helium might contain some fission products, depending on the efficiency of the gas-purification system. A sudden breakage could result in a 15-fold increase in gas volume, but there is a safety expansion chamber to take care of such an accident. This 15-fold expansion is to be contrasted with the 1,700-fold expansion possible when liquid water is suddenly converted into steam. Gas-cooled reactors do not have the boiler-explosion-type of hazard to which water-cooled or -moderated systems are subject.

There is nothing that can lead to a chemical explosion such as is theoretically possible with reactors that involve sodium and water or aluminum and water. There is nothing about the system of graphite, helium, uranium carbide, and molybdenum that can lead to mechanical failure, explosion, or corrosion below 4,000° F. Corrosion of metals by water and of steel by hot sodium are not involved.

The materials used in the reactor described here can withstand temperatures at least 2,000–3,000° F higher than can be used with steel, zirconium, beryllium, or aluminum, especially when they are in contact with water.

It is difficult to keep all parts of a reactor at a uniform temperature; any local failure in the circulation of the coolant could lead to local hot spots. To be safe, the average temperature of the coolant must be kept considerably below the danger point of the materials.

Although local spots in the reactor can be permitted to go to 4,000° F and higher, the temperature limitation in the reactor circuit is the stainless-steel heat exchanger. This cannot be permitted to go above 1,400° F and the temperature of helium leaving the reactor will be kept down to 1,350° F. The helium from the various cooling channels will be mixed before reaching the heat exchanger, and there is less danger of melting or weakening the stainless steel when it is heated by this mixed helium stream than when a boiler is heated by burning coal.

It may be possible to increase the safe-operating temperature of the heat exchanger somewhat by using nitrogen instead of air in the gas-turbine circuit. Stainless steel can withstand continued exposure to higher temperatures if oxygen is excluded.

Fuel Reprocessing

Cheap reprocessing of partially spent fuel units is vital to the economic success of atomic power. If fuel units have to be removed from a reactor at very frequent intervals, dissolved in nitric acid, separated from fission products and reconverted into new fuel units, the cost is excessive. The cost can be reduced in two ways—first, by increasing the time the fuel units remain in the reactor, and second, by lowering the cost of fuel reprocessing. The design suggested here has advantages in both respects.

Reprocessing steps. To prepare the fuel for reprocessing, the graphite cartridges containing the UC_2 fuel are released from the bottom of the fuel channels and collected in hoppers. They then are crushed by hammers and the partially spent and radioactive powdered UC_2 fuel is sifted from the larger fragments of graphite cartridges; or they are heated at 1,800° F in a closed system in which oxygen is circulating with suitable replenishment. The carbon dioxide is absorbed in sodium hydroxide.

When treating the partially spent UC_2 after operation of the reactor, the

oxygen is circulated in a closed system over adsorbing material at low temperatures to remove xenon, iodine, and other volatile fission products released by the heating.

The chemical processing consists of several simple operations carried out with as many of the cartridges as can be handled at a time in view of the critical mass and the intense radioactivity.

1. The uranium carbide and graphite are heated to about 1,800° F in oxygen or air to oxidize the carbide to oxide. In an experimental check, 2 hours were sufficient to convert a small sample of UC_2 to UO_2 and U_3O_8. The original UC_2 and C lost considerable weight during heating and the product, containing 90% U, dissolved readily and completely in 3-molar nitric acid without gassing.

2. The uranium oxide formed by heating the carbide dissolves in the nitric acid, forming uranyl nitrate. There are no metals present to give oxides of nitrogen such as are produced when uranium metal, aluminum, zirconium, or other canning metals are used. The fact that no gases are evolved is an advantage because any escaping gas will carry some radioactivity and require additional equipment for containment and purification.

3. The solution is allowed to stand to permit any slight residue of graphite to settle; then it is decanted. The clear solution of nitric acid containing the uranium and fission products is treated with tributyl phosphate and kerosene to remove the uranyl nitrate by solvent extraction. Experience in this laboratory with tributyl phosphate extraction shows that the uranium is removed completely and quickly. It is assumed that most of the fission products will be separated quickly from the uranium by this extraction. The usual problem of radioactive damage to the organic solvent must be faced.

4. The uranium dissolved in tributyl phosphate and kerosene is precipitated with ammonia gas, giving a gelatinous precipitate of ammonium diuranate. Again, extended experience with this reaction shows that precipitation is complete and rapid. Then the ammonium diuranate is removed with a centrifugal filter.

5. The ammonium diuranate is heated to about 800° F to form the oxide, U_3O_8. It is purified and mixed with graphite powder and heated without access of O_2 to give UC_2 for reuse.

6. The fission products and the aqueous nitric-acid solution are evaporated to dryness and sealed in welded stainless-steel tubes for storage. This dry material in the tubes can be used for heating air; it also can be used as an intense source of gamma radiation. If the heat and radioactivity are too intense, the fission-product residue can be diluted with graphite powder.

7. The uranium carbide from step 5 is mixed with graphite and loaded into the graphite cartridges as described previously.

8. All the operations described—removal of partially spent fuel units, solution, solvent extraction, precipitation, filtering, heating, and reloading—are done by remote control. No hand operations are necessary.

9. Since all the chemical processing and reloading is done by remote control, with no machining operations, it is clear that a long cooling period for radioactivity decay is not necessary except to decrease radiation effects on the solvents. The reduced cooling period tends to reduce the inventory of U^{235}—thereby reducing capital investment.

Four basic alternatives. The chemical processing of the UC_2-graphite fuel units can be handled in four ways:

1. The partially spent fuel can be sent to a central processing plant that services spent fuel from several reactors.

2. A new processing plant can be built adjacent to the reactor. The cost of such a processing plant with its radioactive hazards is so great that a large capacity would be desirable.

3. A small expendable processing plant is suggested. For 10% enrichment, only 13.7 kg of U^{235} and a total of 137 kg of uranium and fission products is the total material processed. After a few days the solvents are distilled off and the unit is buried in concrete; no attempt is made to decontaminate the machinery or to use it again. A concrete burial vault in the form of a 10-ft cube is suggested, with stainless-steel lining and outer covering.

4. A final alternative is to carry the fission of the U^{235} so far (perhaps more than 66% burnup) that one can afford to discard the remaining U^{235} and store all the material in vaults without attempting any reprocessing.

Recommendation

There now seems to be a realization that more emphasis should be given to gas-cooled reactors. The construction and operation of a high-temperature gas-cooled reactor would make important contributions to the power reactor development program.

An experimental hole could be installed in the reactor for carrying out experiments with intense neutron radiation at temperatures up to 1,500° F, thus giving additional opportunities for research.

The power reactor proposed here appears to have advantages in simplicity and small investment cost that may appeal to nonindustrialized countries. Possibly the United States can loan them the necessary enriched uranium, like a match, with which they can start breeder reactors to help solve their power problems.

It is hoped that some industrial companies or laboratories will be interested in financing, constructing, and operating the type of power reactor described here. It also is hoped that such a program may have the active support of the U. S. Atomic Energy Commission.

Future Developments

The second power reactor would certainly be increased from 5 Mw to 10 Mw. Such a turbine and dynamo would cost more, but the rest of the equipment would not change very much, except for the blower and heat exchanger, which would be doubled in size.

The heat exchanger would be eliminated in a later installation if the following conditions can be met: (a) low radioactive contamination; (b) small turbine leakage; (c) a helium turbine is developed or ceramic or gas-cooled control rods are developed so as to permit using nitrogen as the reactor coolant.

Expansion to large installations can come when large closed-cycle gas turbines are developed. A 60-Mw turbine for helium has been designed (*8*). There appears to be no serious limitation to large sizes.

On the other hand, there are arguments for multiplying the 10-Mw units for a single power station. This type of reactor is uniquely favorable for use in nonindustrialized areas; and it would be much easier to transport 10-Mw-size machinery, pressure vessels, and special equipment overland to distant places than it would be for 50–100-Mw sizes. The multiple units permit a good deal

THIS REACTOR HAS . . .

. . . These definite advantages . . .

Simpler fuel cycling. *Reprocessing and refabrication of fuel units is infrequent, inexpensive, and is done entirely by remote control.*

Lower inventory. *Fuel inventory for radioactivity decay is not large.*

Easier fuel fabrication. *There are no metals to melt, no machining of fuel units, and no close tolerance of dimensions.*

High-temperature materials. *There can be no damage from localized hot spots because there are no low-melting-point metals.*

Neutron economy. *Neutron absorption is low in the coolant, moderator, and fuel units. Since the fuel units are not canned, there is no canning metal and no metal in cooling channels to absorb neutrons. The high neutron economy gives better opportunity for nuclear conversion and breeding.*

No corrosion. *No corrosion can take place because there are no metals in the fuel rods, no water, and because helium is chemically inert.*

Explosion-free. *There is no danger of explosion because there is no way to produce gases by overheating or by chemical action.*

No leakage. *There is no leakage of helium or volatile fission products from the reactor circuit because the helium is entirely enclosed. There is no contamination of the turbine circuit because it is separated from the reactor circuit by a heat exchanger.*

Water not needed. *Really cold cooling water is not required for the turbine because the higher temperature is so high that a large temperature difference can be maintained even with moderate cooling. Air-cooling becomes a possibility. This fact is important in arid regions where cooling water is scarce.*

Fewer auxiliaries. *Water softeners and similar auxiliary machines for steam plants are less important.*

Efficient, flexible. *The gas turbine is efficient (30%); it is simpler to operate and more flexible than steam turbines.*

The reactor proposed here is different from other types now under design or construction: gas cooling, high temperatures, and gas turbines should be investigated.

. . . along with these uncertainties

Heat transfer. *The heat conductance of the uranium carbide and graphite is good and the active fuel material has a radius of only 3 mm. But the central part of the fuel rod might become undesirably hot, although not hot enough to create a hazard for the uranium carbide or graphite in the helium atmosphere. Heat transfer experiments are needed.*

Fission-product deposition. *Some of the fission products will have appreciable vapor pressures at the highest temperatures of the fuel units. Most of these will be retained in the graphite cartridges, but some undoubtedly will be driven out. It is difficult to predict where in the reactor-heat-exchanger circuit they will be deposited. A single loaded cartridge exposed briefly in a test reactor and then heated will give valuable information.*

High-temperature-reactor control. *The temperature effect on the velocity of the thermal neutrons will tend to control the reactor power output. There is no experience with a reactor operating above 1,300° F, or with a reactor having such an extreme range of temperatures.*

Control reliability. *The helium does not absorb neutrons and there is no automatic control due to a density change in the coolant such as exists in some other reactors. On the other hand, there is no fluctuation in power level due to changes of pressure. A heavy responsibility is placed on the control rods and control mechanisms.*

Leaktightness. *The large heat exchanger must be free of pinhole leaks so as to prevent contamination of the turbine. There also might be difficulty in keeping the helium contained in hot steel vessels. It is essential that the stainless steel be of such character that helium can not diffuse through it at temperatures below 1,300° F. The leakage of helium at high temperatures can be tested easily.*

Erosion of graphite. *Erosion of hot graphite by helium streams is probably negligible, but should be tested.*

Some of these questions can be answered by laboratory experiments; others need mockup tests; but still others can be answered only by actual operation of the reactor.

of flexibility in operation and in shutdown for reloading or repairs, and they would minimize radioactivity hazards in case of accident.

In long-range planning, the development of a molybdenum or tungsten turbine designed to operate with helium at 3,000 or 4,000° F should be undertaken. The thermodynamic efficiencies are greater at these temperatures and so it should be possible to use smaller, less efficient turbines and allow some low-temperature heat to be wasted. These metals cannot be used with combustion fuel because they will oxidize, but with helium there is a unique opportunity to pioneer in a new high-temperature range.

* * *

The author has had the benefit of valuable advice and criticisms of many friends in planning the power reactor described here. He wishes to acknowledge particularly the help of Joseph C. Carter of Argonne National Laboratory, H. G. MacPherson of the National Carbon Research Laboratories, H. B. Saemann of the Nordberg Manufacturing Co., and S. T. Robinson of the American Turbine Corp. For the early background material, he is indebted to the Metallurgical Laboratory of the Manhattan District, operated by the University of Chicago, and to the power pile division of Oak Ridge National Laboratory as operated by the Monsanto Chemical Co.

BIBLIOGRAPHY

1. F. Daniels. Suggestions for a high-temperature pebble pile, MUC-FD-8 (1944)
2. C. Rogers McCullough, et al. Summary report on design and development of a high-temperature gas-cooled power pile, MON-383 (1947)
3. F. Daniels. Suggestion for an experimental power reactor. An impregnated graphite nitrogen-cooled reactor and gas turbine, ANL-4448 (1950)
4. F. Daniels, *Reactor Sci. and Technol.* **4,** No. 2, 7 (1954)
5. J. J. Katz, E. Rabinowitch, "Chemistry of Uranium," p. 220, (McGraw-Hill Book Co., Inc., New York, 1951)
6. O. Heusler, *Z. anorg. u. allgem. Chem.* **184,** 363 (1926)
7. W. G. Hendrickson, F. Daniels. The thermal fixation of atmospheric nitrogen. II, *Ind. Eng. Chem.* **45,** 2613 (1953)
8. S. T. Robinson, "Design Study for a 60-Mw Closed-Cycle Gas-Turbine Nuclear Power Reactor," American Turbine Corporation (1954)

Progress on Materials—Key to Gas-Cycle Reactor Potential

By enriching fuel and by increasing pressure of gas used as reactor coolant, heat transfer properties are improved, core and pressure vessel are made smaller, and cost is cut. Although steam cycle could be used, gas-cycle holds stronger cost promise

PRESSURIZATION of the coolant gives gas-cooled reactors new attractiveness for power purposes. The Oak Ridge and Brookhaven gas-cooled research reactors served their designers' purposes well, but such low-pressure reactors are not suitable for power production. Table 1 shows the favorable power potential of gas-cooled units.

Characteristics of gas-cooled power reactors, both closed-cycle and open-cycle, were described recently at a meeting of the Washington chapter of the American Society of Mechanical Engineers. Table 2 compares the closed-cycle designs covered at the session. Here is an analysis of the content of the papers presented by: T. Jarvis, Ford Instrument Co.; J. G. Gallagher, Alco Products, Inc.; C. H. Fox, Glenn L. Martin Co.; and S. T. Robinson, American Turbine Corp. (*1–4*). The figures on p. 44 compare general merits of open-cycle and closed-cycle gas systems.

The possibility of eliminating the heat exchanger, the relatively noncorrosive nature of the gases, and the potential of materials that could be used at high temperatures in gas-cooled reactors make such reactors attractive for power generation. Thus, the gas-cycle plant would be relatively simple compared with those using water or metal coolants and a steam system.

Although the gas-handling and turbine portions of the plant are relatively straightforward, particularly in modest-sized plants, materials problems and uncertainties must be resolved.

Materials

The reactor for a gas-cycle plant must operate at temperatures high enough to supply the turbine with gas at temperatures of 1,200–1,500° F. This means that the fuel-canning materials should be capable of withstanding temperatures considerably greater than these. Some metals can do this. But if thermal-stress and -shock problems can be solved or eliminated, ceramics offer the possibility of much higher core temperatures (~2,000–3,000° F) than can be developed safely using metallic fuel elements.

Gases. A number of working gases can be chosen that will be clean, uncontaminated, stable, relatively noncorrosive, and capable of heating without changing state or properties.

Atmospheric air is used in all open-cycle systems. It presents some corrosion problems that limit the core temperature. Also, excessive atmospheric contamination by radioargon or escap-

TABLE 1—Reactor Heat-Transfer Comparison*

Reactor	*Power density (kw ht./ft³ of core)*	*Specific power (kw ht./kg fuel)* U^{235}	*Specific power (kw ht./kg fuel)* U	*Max. heat flux (Btu/hr/ft²)*
Gas-cooled research reactors				
X-10 pile (ORNL)	54	11.1	0.087	7,300
Brookhaven pile (BNL)	34	70	0.61	20,730
Pressurized-gas-cycle reactor				
Typical design†	~900	~1,500	~75	~400,000
Pressurized-water reactors				
Materials Testing (MTR)	8,300	10,000	11,000	294,000
Pressurized Water (PWR)	—	—	—	382,000
Unpressurized sodium-cooled reactor				
Sodium Graphite (SGR)	180	565	10	350,000–850,000

* Data from ref. *1*, which uses data from Geneva papers and from AECD-3646, Vol. 2.

† Design proposed in ref. *1*. Relatively crude nuclear calculations indicate that good neutron economy can be maintained with a free flow area of 20% of the total area. Thus, power densities of 4,000–5,000 kw/ft³ probably are attainable with gas-cooled reactors.

ing fission products must be prevented when using this cycle. In closed-cycle reactors, high-temperature air will attack uncanned graphite moderator.

Nitrogen technology is fairly well established. Nitrogen eases reactor temperature limitations and moderator problems; it is inert toward graphite. Stainless steel is usable at 1,800° F if the nitrogen is free of oxygen. However, nitrogen will react with molybdenum or tungsten control rods that are otherwise usable at higher temperatures. Development of ceramic control rods that can withstand mechanical strains will make nitrogen usable at high temperatures. Nitrogen would absorb some neutrons and produce some radiocarbon in the coolant circuit.

In the Jarvis design, the heat-transfer coefficient would be 80% greater with helium instead of nitrogen. Helium virtually eliminates corrosion problems as it is quite inert toward reactor structural materials. Its neutron-absorption cross section is extremely low and it forms no radioactive product.

Carbon dioxide is another possibility. Gas selection should be based on thermodynamic, chemical, nuclear, and state-of-the-art considerations.

Fuel elements. Once they are sufficiently developed for use, ceramic or cermet-ceramic fuel elements will be more desirable than metallic elements. Their attractiveness will be based on their low neutron absorption, higher working temperatures, and easier reprocessing. But the designs presented keep fuel temperature low enough to use metals with available techniques.

The two designs described by Gallagher use stainless steel UO_2 fuel elements—tapered tubes for the air-cooled reactor and plates for the N_2-cooled unit. Elements for the Jarvis design are internally cooled hexagons of SS-316 and UO_2.

The 4-ft-high tapered tubes, made of two 1.036-in.-wide fuel-bearing plates brazed at top and bottom to two tapered plates, must be tested for 1 yr at slightly less than 1,500° F. High-temperature high-burnup properties and possible effects of nitriding must be investigated for the plate-type element.

Moderator. Beryllium, beryllium oxide, and graphite are materials considered. Chemical stability must be preserved under operating conditions above 1,000° F.

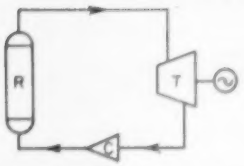
For an open-cycle plant, the moderator should have good long-time stability in stagnant air; the moderator could be canned in an inert gas to keep it from contacting the air, but this adds complexity. Since graphite is attacked by hot air and beryllium corrodes severely in 1,478° F air for 12 hr or in 1,650° F air for 1 hr (a white surface

TABLE 2—Comparison of Four Single-Loop Gas-Cycle Reactors

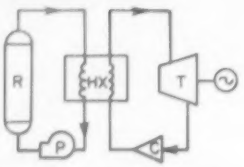
Characteristic	*Proponent*			
	Gallagher	*Gallagher*	*Jarvis*	*Robinson*
Cycle type	Open	Closed	Closed	Closed
Power (Mw)				
Plant output, net (elec.)	0.2	2	15*	60
Plant output, gross (elec.)	0.25	2.5	—	—
Reactor output (heat)	2	7	44	148.5
Net efficiency (%)	10.2	31	34	40.4
Reactor coolant				
Gas	Air	Nitrogen	Nitrogen	Helium
Flow rate (lb/sec)	8.25	54	296	220
Reactor size (ft)				
Core diameter	4	4.1	5	—
Core height	4	4.1	4	—
Vessel diameter	—	8	9	—
Vessel height	—	—	13§	—
Reflector thickness	0.5	1.45‡	1	—
Moderator				
Material	8,000† hot-pressed BeO blocks	Graphite	Graphite	—
Density (gm/cm³)	2.76	1.9	1.6	—
Fuel				
Initial loading (kg U^{235})	<25	<25	25–50	—
Enrichment (%)	—	—	10	—
Form	UO_2	UO_2	UO_2	—
Element shape	Tapered tubes	Plates	Hexagons	—
Cladding	Stainless steel	Stainless steel	SS-316	—
No. of elements	800	302	36	—
Square lattice spacing (in.)	1.5	2.5	—	—
Core life (Mw-yr)	4	—	20	—
Full-power life (days)	320	—	274	—
Temp. coeff. of reactivity ($\Delta k/°C$)	Negative	—	-10^{-5}	—
Temperature (°F)				
Moderator	1,000	1,000	—	—
Fuel	1,500	1,500	1,700	—
Gas entering reactor	451	764	760	878
Gas leaving reactor	1,325	1,220	1,300	1,400
Gas leaving turbine	878	829	815	942
Pressure (psia)				
Gas entering reactor	64.7	396	534	1,000
Gas leaving reactor	62.76	384	512	985
Gas leaving turbine	15	120	127.8	425
Turbine	Jupiter T-520 (Solar Aircraft Co.)	Tuco-52 (Escher Wyss)	Escher Wyss	Escher Wyss
Cost				
Installed ($/kw)	—	—	250 ± 75	—
Power (mills/kwh)	—	—	12 ± 3 at 80% L.F.	—

* Jarvis also expects that a 240-Mw plant will be feasible. It would cut $/kw costs sharply. Pressure vessel would have 13-ft dia; 1,000 psi. The closed-cycle gas turbine would be used. Fuel elements would be plates or tubes.
† Including reflector.
‡ Reflector is reactor-grade graphite (AGOT) of 1.71 gm/cm³.
§ Including control-rod mechanisms.

Closed Cycle

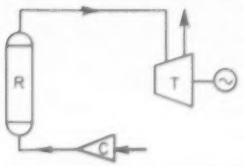


SINGLE LOOP means no heat exchanger; needed efficiency higher, lower capital and operating costs. But operation and maintenance is complicated by using "hot" gas in turbine; gas might corrode core materials or pick up fission products

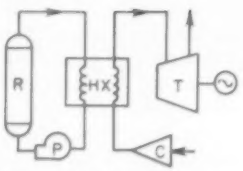


DOUBLE LOOP keeps turbine free of "hot" gas and corrosion products from reactor. It is less efficient and costs more due to heat exchanger, pumps, piping, etc. Permits use of different gases in reactor circuit and turbine circuit

Open Cycle



SINGLE LOOP is simplest and cheapest plant to build, but radioactive gases, corrosion products, and fission products are exhausted to atmosphere. No need to supply special gases, but corrosion in air-cooled reactor imposes temperature limit on cycle



DOUBLE LOOP eliminates turbine-contamination problem, but throws away open-cycle's prime advantage—simplicity. Containment problems are more difficult in open-cycle plants, which generally are otherwise cheaper than closed-cycle plants below 1 Mw

film forms after 1 hr at 1,650° F), beryllium oxide blocks are specified for the open-cycle design—despite BeO fabrication problems.

Beryllium oxide is quite stable and inert at high temperatures in most gases of interest. High-speed air will not directly contact the BeO, but the blocks are not canned. The blocks are subjected to very minimum stresses and integrity can be the barest minimum—cracking is permissible. Berylia and water vapor react above 1,250° C to form a volatile compound. But the reaction should not be a serious problem at the temperatures considered here. Still, the toxicity situation should receive careful study after small-scale tests determine the BeO weight loss under operating conditions.

For closed-cycle plants using a coolant less corrosive than air, a moderator of graphite appears to give a larger and cheaper reactor. BeO might be more desirable where minimum weight and size are important. The moderator material should be chosen on mechanical, nuclear, and state-of-the-art bases.

Problems. A number of technical problems need to be solved before a gas-cycle reactor plant is built. In addition to those already discussed, most of these uncertainties lie in the fuel elements. Questions also arise regarding over-all system stability and safety, as well as moderator-coolant compatibility in operating radiation levels. Experimental checks are desirable.

Fuel-element performance should be checked theoretically and experimentally for the following factors: maximum operating temperatures, mechanical stress, thermal stress, radiation damage, fission-product diffusion through fuel-element walls, mechanical and reactivity limitations of fuel burnup, and maximum burnup. Present knowledge indicates that these problems can be solved and performance considerably improved through materials development.

Design Innovations

Several design features of the units described are worthy of note. The design presented by Jarvis has double-wall piping between the reactor and the turbocompressor so that thinner piping can be used. With the hotter gas in the inner pipe, the pressure difference across this hotter pipe will be only that of the pressure difference across the reactor rather than the maximum pressure of the system. The pressure vessel uses the same principle.

In the reactors described by Gallagher, pressure drops and fuel temperatures are minimized by tapering the flow passages past the fuel. The passage hydraulic diameter is varied radially to obtain the same temperature rise in each cell. Tapering the flow passage axially gives constant surface temperatures and minimum pressure drop. The outlet heat-transfer coefficient is increased, which offsets the rising air temperature.

Turbines

Small industrial open-cycle gas turbines are generally available. For the small 200-kw plant, the open-cycle is used because of its simplicity. The Jupiter T-520, developed by Solar Aircraft Co., was selected. Designed for shipboard generator sets, its total installed weight is 854 lb and it uses a single combustor. At 20,000 rpm, 75° F compressor inlet, and 1,325° F turbine inlet, it produces 400 bhp. When the reactor replaces the T-520's combustion chamber, the expansion ratio is cut because of the 3% $\Delta p/p$ across the reactor and the 2% $\Delta p/p$ back pressure from the filter and exhaust ducting. For this 5% $\Delta p/p$, net output will be 200 kw, or 250 kw brake.

Closed-cycle gas-turbine plants have operated using gas heated by burning oil, coal, and peat, as well as by using waste heat from an exothermic chemical reaction. Reactor-produced heat would give a relatively clean and dry working fluid that would permit improved turbine design and performance. During the 15 years that Escher Wyss Ltd. of Zurich, Switzerland, and their licensees have been developing closed-cycle gas-turbines plants, about a dozen plants ranging from 500 hp to 12.5 Mw have been, or are being, built. Terminal efficiencies range 20–30%.

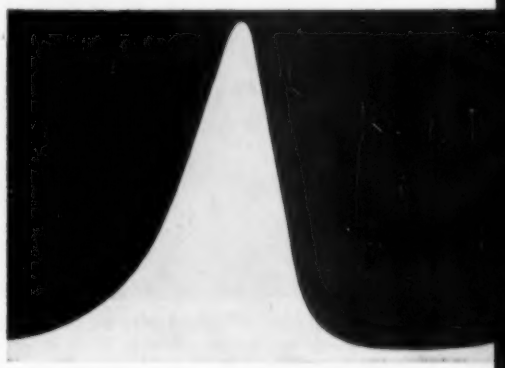
The closed-cycle gas-cooled nuclear plant offers small space and volume requirements with excellent efficiency. Extensive application probably will be in plants of moderate size (up to about 30 Mw) at first. A 5-Mw nuclear turbine is fully designed and can be delivered within 18 months. A 10–15-Mw model is designed and probably could be delivered within two years. A 60-Mw turbine for helium has been designed (*5*). Larger sizes are not impeded by any serious limitations.

BIBLIOGRAPHY

1. T. Jarvis, Nuclear reactors for large gas turbines*
2. J. G. Gallagher, Small gas turbine reactor plants*
3. C. H. Fox, The open cycle gas turbine in reactor power systems*
4. S. T. Robinson, The closed cycle gas turbine nuclear power plant*
5. S. T. Robinson, "Design Study for a 60-Mw Closed-Cycle Gas-Turbine Nuclear Power Reactor," American Turbine Corp., 1954

* Presented to the ASME Symposium on Nuclear Gas Turbines, Washington, D. C., December 8, 1955.

AEC Steps Up Reactor Safety Experiments



A comprehensive new program is being set up to help assure reactor design and operating safety. It consists of testing operating reactors, developing fuses, studying molten metal-water reactions and spontaneous ignition of reactor materials, and finding the most practical structures for containing fission products

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SAFE OPERATION of nuclear reactors is one of the most important factors in the early use of fission energy. For efficient utilization, nuclear plants must be operated in highly industrialized areas with assurance that accidents to these plants will not endanger the health and safety of the public. To permit this assurance, the Atomic Energy Commission is striving to obtain basic information on the safe design and operation of reactors.

Argonne National Laboratory made the first tests primarily directed to defining reactor safety and behavior of reactors under adverse operating conditions. These pointed the way for advancement of experimental work in this field. Prior experiments on reactor behavior during power surges at Los Alamos Scientific Laboratory, Oak Ridge National Laboratory, and other installations were restricted because of the possibility of damage to a valuable research tool and surrounding laboratories. The Argonne experiments, or Borax (Boiling Reactor Experiment) tests, carried out at the National Reactor Testing Station in '53 and '54 demonstrated that valuable data on reactor behavior could be accumulated by remote operation of a minimum-cost test facility where deliberate or inadvertent destruction of test facilities could be tolerated (*1–3*).

In its now-intensified program, AEC plans to test each of the major classes of reactors to determine empirically their safe upper operating limits. Included are pressurized and unpressurized, boiling and nonboiling thermal reactors, both homogeneous and heterogeneous, and fast-reactor systems. The tests are planned to show in a quantitative way what phenomena contribute most to self protection in reactors so that future designs can incorporate these inherent safety mechanisms to the maximum possible extent. This program also will permit a more rigorous safety evaluation of future reactor designs.

An integrated reactor safety research and development program must include many types of experiments to cover the various aspects of the subject. The following questions indicate the scope of the program:

1. Under what operating conditions will a given type of reactor damage itself?
2. Will the fuel elements melt?
3. Will the molten fuel elements enter into an explosive chemical reaction with the reactor coolant?
4. Will the reactor pressure vessel contain the energy released in the nuclear and chemical events?
5. If the pressure vessel fails, will the containment structure maintain its integrity, prohibiting release of fission products to the surroundings?

The last four areas of investigation are susceptible to experiments not involving use of a nuclear reactor.

Reactor tests will be made to study the rates of the effects of temperature and power coefficients with time as influenced by perturbations in steady-state operating conditions. The perturbations might be caused by intro-

ARGONNE National Laboratory's Borax-1 shutting itself down safely by expelling water after being made supercritical by 2.1% k_{eff}. Such tests demonstrated value of reactor safety experiments (3)

duction of excess reactivity by control-rod action or removal of irradiation containers, failure of coolant flow, or abrupt change in coolant temperature.

Construction of two general types of reactor-transient test facilities was begun early in 1955. Each facility is designed for simplicity of expansion for future experiments. A heterogeneous-reactor test facility (SPERT—Special Power Excursion Reactor Tests) is located at the National Reactor Testing Station in Idaho. It is operated by Phillips Petroleum Co. The reactor projects are in various stages of operation, construction and design. A small homogeneous-reactor testing facility (KEWB—Kinetic Experiments on Water Boilers) is under construction by North American Aviation Corporation at its Santa Susana, California, site.

"SPERT" Tests

The SPERT facilities are planned to provide test information on five reactor concepts. The installation consists of a central control building for remote control of test pits located at a distance of ½–¾ mile from the operating center. Each pit is isolated so that if an unexpected energy release occurs, damage will be limited to that one specific experiment. The pits are susceptible to severe contamination and may be abandoned if the decontamination problem is excessive.

SPERT-1 is an unpressurized light-water-moderated reactor using aluminum-clad Materials-Testing-Reactor-type fuel. The facility is already in operation, having gone critical July 11, 1955. Transient tests have been proceeding ahead of schedule. The fuel elements have been structurally strengthened to minimize damage by the increased pressure induced during power surges. Periods (time of increase of reactor power by a factor of e) of about 7 msec have been reached with no apparent damage.

SPERT-2 incorporates a low-pressure vessel designed to facilitate changes in reflector configuration and to enable study of various types of moderators, such as graphite, heavy water, light water, and beryllium. Data obtained with pressures in the range of 300 psi will allow extrapolation of data to higher pressures. This will ease the problem of frequent and more costly and difficult modifications of high-pressure vessels. Construction of this facility will begin during 1956.

SPERT-3 is a high-pressure light-water-moderated reactor with facilities for testing various core assemblies. It will operate at pressures of about 2,500 psi. Information obtained from these operations will be applicable to the Submarine Thermal Reactor, Submarine Advanced Reactor, Army Package Power Reactor, and similar reactors. Construction will begin in 1956.

SPERTS 1, 2, and 3 will provide information useful in assessing water-cooled heterogeneous reactors using fully enriched uranium. They will include boiling and nonboiling systems.

SPERT-4 is planned as a fast-reactor system to be designed, fabricated and made ready for test by 1958. This reactor concept is similar to that of the fast reactors designed by the Argonne National Laboratory and Atomic Power Development Associates. These investigations will provide information on the vastly differing conditions of reactor systems with short neutron-generation times.

SPERT-5 is planned as a reactor using uranium of low enrichment. The behavior of this reactor is quite distinct from that of other types. It will provide safety data for the large unenhanced-fuel-reactor types contemplated for foreign facilities and for the existing graphite types. But it is realized that duplication of the behavior of the extremely large reactors on a small scale is a difficult problem. This reactor is also planned for the 1958 expansion of the test facilities.

"KEWB" Tests

The KEWB facilities are designed to conduct power-transient tests on small homogeneous reactors. The ultimate objective is to provide data for the more sophisticated design of maximum-safety reactors for application and use in research, medical, and industrial installations.

Three core-configuration tests and gas-detonation experiments are planned to carry out a complete safety-test program for this type of reactor.

KEWB-1 is a spherical-core graphite-reflected liquid-fuel reactor. Of immediate interest from this test will be information pertinent to the University of California Radiation Laboratory and Armour Research Foundation research-reactor designs. The reactor is contained in an underground gastight structure designed to contain any gaseous fission products in the event of a fuel spill or mishap. Transient tests will proceed stepwise with extreme caution. Power will be increased and periods decreased in small stages to avoid any possible rupture of the reactor core. The test facility is expected to go critical in Spring, 1956.

KEWB-2 is a proposed expansion of the present facilities. It will be used to test various core vessel configurations and attempt to determine the magnitude of the energy release, the mecha-

nism of shutdown, and the salient design features required for safety in a water-boiler reactor.

KEWB-3 is a proposal for gas explosion experiments. The objective is to obtain information from hydrogen-oxygen explosions that can be used to define a safety factor that then can be incorporated into the design of reactor core vessels. This factor of safety will be applicable to pressure-resistance requirements that might be imposed on the core vessel in the event of ignition of the gases of radiolysis produced during a nuclear transient.

Fuse Development

A prototype of a reactor fuse that uses a neutron absorbing gas has been developed by North American Aviation. During the past year many in-pile tests have been conducted to determine time of response and the radiation effects on these gases and their containers. These tests have proven the feasibility of the fuse and full-scale in-pile tests are proposed for 1956.

Another concept of a reactor fuse now under study consists of a ballistomechanical device using a cartridge-encased propellant to activate the insertion of a poison rod or the removal of a fuel element. Each of these fuses is proposed as an integral internal part of a reactor as an additional feature of all types of reactors. The reactor-transient test facilities are excellent devices for tests of fuse developments.

Metal-Water Reactions

Basic research and study of molten metal-water reactions are being conducted by the Aerojet-General Corporation for the Atomic Energy Commission. One goal is to find or develop materials that will effectively retard the explosive reaction of molten metal with water.

The scope of the work includes: (a) a semifundamental study and test to determine the reaction rates and reaction efficiencies of reactor fuel material with water and the effect of retardants, (b) a study and test of the reactivity of reactor structural metals with water, (c) a study of the corrosion rates of materials near their melting points.

Fuel Ignition Studies

Very little is known of the mechanisms of spontaneous ignition of metals. The need for more information on this is evidenced by the spontaneous uranium fires experienced in some AEC installations. Fires have occurred in massive pieces of metal as well as in chips, turnings and powders. Similar pyrophoric properties have been noticed in other metals used in reactor structures.

The Argonne National Laboratory is doing basic research in the field of fuel and metal ignition. The object is to understand the chemical reactions involved in their ignition so that fires and explosions of reactor fuels can be prevented.

Containment Tests

Reactor containment-structure tests supported by AEC contracts are being conducted at the Naval Ordnance Laboratory and at the Aberdeen Proving Grounds. The object of the program is to: (a) predict damage to containment structures caused by uncontrollable reactor excursions; (b) devise means of containing products of explosive reactor incidents; and (c) devise methods of minimizing damage to facilities and environs.

Reactor accidents are fundamentally different from high-order explosions. Thus, part of this work entails developing a high-explosive technique to simulate a reactor runaway. This work also will make use of scale models to determine scaling laws and safety factors for use in the design of containment housings for reactors.

Revisions

The comprehensive program will be fraught with many difficulties. These are caused by the instrumental limitations in measuring fast, elusive, and little understood variables during the sometimes violent environment of a pulsed reactor and the problems in extrapolating the data to other reactor cases. Thus, the program represents only plans for the future and not an assured short-term goal. As portions of the program are completed, it is hoped that more meaningful and efficient experiments can be designed for the succeeding steps.

Summary

The experimental program on reactor safety is intended to obtain quantitative information that will: (a) better define the fundamental physical and chemical phenomena relating to reactor safety; and (b) enable a more meticulous, economical, and safer design of reactor containment structures. The costs of such structures in terms of expenditure per kilowatt of installed electrical power capacity are sufficiently large that the economical use of nuclear power requires detailed consideration of this factor. Unless costs are lowered or eliminated, delay in use of this energy source will result.

The operation of nuclear reactors in areas of dense population and high value is certainly a serious consideration in a developing and expanding nuclear-energy industry. Before this consideration can be acted on favorably, assurances must be made that reactor accidents will result in no damage other than to the plant itself and that even these accidents will be minimized in frequency and severity. This can be done through sound engineering practices based on the results of a thorough research and development program.

The Atomic Energy Commission has accumulated over 12 years of safe reactor operating experience with an increasing number of reactors on stream (*4*). This program will help assure continuation of this record.

BIBLIOGRAPHY

1. J. R. Dietrich, *et al.* Determination of the self-regulation and safety of operating water-moderated reactors (Paper 481, UN International Conference on Peaceful Uses of Atomic Energy, Geneva, 1955)
2. S. E. Beall, C. E. Winters. The homogeneous reactor experiment, *Chem. Eng. Progr.* **50,** No. 5 (1954)
3. NUCLEONICS **13,** No. 9, 40 (1955)
4. R. H. Graham. U. S. reactor operating history: 1943–1954. NUCLEONICS **13,** No. 10 (1955)

Applying Radiation to Industry

That's the subject of a case-study special report scheduled for the May issue of NUCLEONICS. It will cover uses in both industrial research and production processes under the headings:

- **Research**
- **Industrial tracing**
- **Hydraulics**
- **Wear studies**
- **Isotope dilution and tracer analysis**
- **Activation analysis**
- **Beta thickness gaging**
- **Density gaging using gamma services**

Watch for it in the May Issue!

Counting Suspensions in Liquid Scintillators

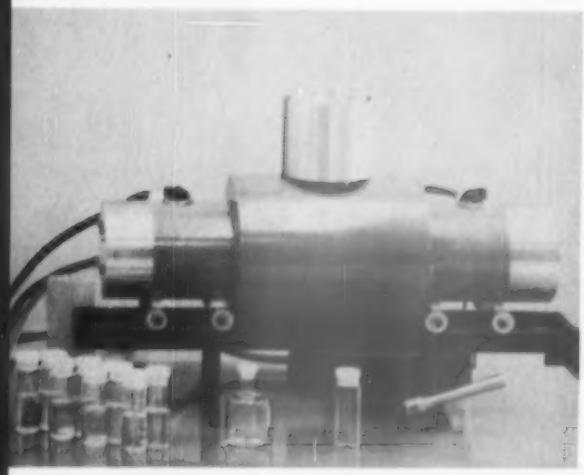

FIG. 1. Liquid scintillation counter showing sample bottles and the nonrefrigerated lead shield with light lock permitting insertion of sample without turning off high voltage

Now materials insoluble in liquid scintillators can be counted with high efficiency. Sample preparation is rapid and counting techniques are straightforward. Settling of the suspension, self-absorption, and light absorption are solvable problems

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COUNTING SUSPENSIONS of solid samples in a liquid scintillator makes many compounds accessible to liquid scintillation counting for the first time. Additional advantages are ease of sample recovery through filtration and absence of conventional quenching problems. Problems present here, but not in solution counting, are self-absorption and light scattering. However, small particle size minimizes self-absorption and stabilizes the suspension at the same time.

We surveyed the potentialities and limitations of suspension counting for several materials and the radioisotopes H^3, C^{14}, S^{35}, and Ca^{45}. The only chemical requirements were that the samples be solids insoluble in toluene. Sample preparation is discussed on p. 50.

Counting Procedures

Here are the procedures and materials we used to count suspensions.

Counting bottles. Kimble Opticlear 10-dram vials, 29 mm in diameter and 85 mm high (including polyethylene cap), were used (Fig. 1). Maximum useful volume was about 35 ml.†

Stock scintillator solution. The liquid scintillator in common use for solution counting also was used in this study. It was 4 gm/l 2,5-diphenyloxazole (PPO) and 0.05 gm/l 1,4-di-[2-(5-phenyloxazolyl)]-benzene (POPOP) in toluene. It represents an excellent compromise among pulse height, economy, and ability to remain homogeneous. Since an inert suspension does not act to precipitate a dissolved solute, the latter criterion

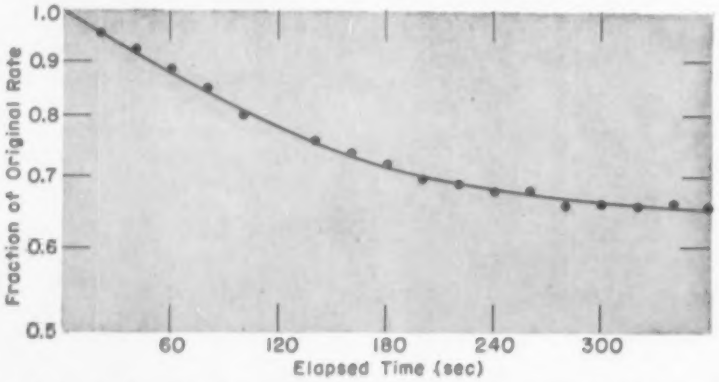

FIG. 2. Effect of settling rate on scintillation counting of a suspension of 20 mg $Ca^{45}C_2O_4$

* Work done under the auspices of the U. S. Atomic Energy Commission.

† In early phases of the study we used a 90-ml Pyrex bottle; some of the results given here were obtained that way. However, experience proved the smaller bottle better.

was not necessary here and 4 gm/l p-terphenyl might have been substituted for the PPO.

After the sample was prepared by grinding and rinsing it into the bottle, stock scintillator solution was added to bring the total volume to 25 ml.

Homogeneous internal standards. Benzenecarboxylic-C^{14} acid (C^{14}-benzoic acid) standard (*1*) dissolved in toluene served as an internal-standard stock solution. Its specific activity was 96,860 dpm/ml.

The internal tritium standard was a toluene solution of dihydrocholesterol-5,6-T_2 (*2*), which was carefully calibrated against standard tritium water by homogeneous liquid scintillation counting procedures. Its specific activity was 276,000 dpm/ml.

Instrumentation. A Los Alamos 540 coincidence system (*3*) was used in this study. The upper-level discriminators were disconnected to eliminate the possibility of encountering the sometimes-useful phenomenon of loss of efficiency with increasing electronic gain. In its routine application, suspension counting will certainly make use of the desirable properties of upper-level discriminators for background reduction and even for "balance point" operation (*4*). Photomultipliers, shield, and sample were at room temperature.

Two lead shields, with accompanying optical systems, were used. One required that the high voltage to the photomultipliers be turned off whenever the sample was about to be removed from the counting region. A second shield (Fig. 1), which was designed for operation outside a refrigeration unit, was constructed with a shutter system that allowed sample changing to be carried out with the high voltage always remaining on. No detectable light leak to the photomultipliers occurred during sample changing.

Settings for high voltage, amplifier gain, and lower discriminator level were such that an unquenched homogeneous C^{14}-solution would count with about 60% efficiency.

Counting techniques. Two methods were available for obtaining repeated counts on a sample. In one, the sample was shaken between each 1-min count and the results were averaged. In the other, a series of 1-min counts was obtained and the results plotted and extrapolated back to zero time. A good fit of the plot to the data substituted for the averaging used in the first method. Shaking the sample between each count was the most popular method and became quite easy with the shield that allowed the high voltage to remain on continuously. In fact, the only occasion for using the second method was with studies of settling rates.

Comparisons of the scatter in counting data with the two shields demonstrated that they were equivalent for counting rates >1,000 cpm. Below 1,000 cpm both shields produced a scatter somewhat beyond that expected by statistics, but the shield with the special optical shutter system was significantly better than the other. It seems reasonable to conclude from this that improved counting stability at low rates results from never allowing the photomultipliers to see light and preserving the continuity of high voltage applied across them.

Data on the efficiency with which the suspensions could be counted were obtained by counting standard suspensions prepared from assayed materials. Duplicate suspensions, to serve as backgrounds, were made from the corresponding inactive samples. Averaging, subtraction of backgrounds from active-sample results, and division by the total activity present gave the desired self-calibrated counting efficiencies. Especially in the extensive C^{14} studies, the procedure was to add a known quantity of the homogeneous internal standard (C^{14}-benzoic acid) to both the background and the active sample and recount. The resulting increases in counts were divided by the known C^{14} activity added, to yield internal-standard counting efficiencies.

Counting Data

It is a very useful practice in homogeneous liquid scintillation counting to determine counting efficiency by adding an internal standard after making a count. This avoids the dangerous assumption that the standard counting solution has the same counting efficiency as the other samples. The internal standard corrects for the vagaries of quenching.

The ratio of suspension counting efficiency to homogeneous internal-standard counting efficiency is denoted by f. If f is independent of scattering and absorption of light by the suspension and if it depends only on self-absorption of the beta particles, controllable by reproducibility of grinding, then knowledge of f will make the homogeneous internal standard very useful in suspension counting.

TABLE 1—Suspension f Values

C^{14}-labeled suspended material	*Weight suspended (mg)*	*f**
$BaCO_3$	19.4	0.91
	38.0	1.01
	41.5	0.93
	94.7	0.94
	101.4	0.92
	219.7	0.93
	234.9	0.96
	avg. =	0.94 ± 0.02
Phenylalanine	15.3	0.97
	37.3	1.04
	39.6	1.02
	101.7	0.98
	107.0	0.99
	242.5	0.90
	250.6	0.92
	avg. =	0.97 ± 0.02
Liver	20.0	1.05
	20.0	1.07
	60.0	1.01
	60.0	0.98
	avg. =	1.03 ± 0.02
Bacteria	20.2	1.02
	59.4	1.02
	120.0	1.02
	avg. =	1.02

* Ratio of suspension-counting efficiency to homogeneous internal-standard counting efficiency.

C^{14}. Table 1 gives f-values for various concentrations of $BaCO_3$, phenylalanine, liver, and bacteria when counts were made in the large bottles; f is reasonably constant in each case. The average values seem to be independent of the color present in the liver samples and the high opacity in the larger concentrations of $BaCO_3$ and phenylalanine.

These f-values are so close to 1 that they indicate almost no self-absorption.

Because f-values of about 1 were obtained for the biological materials, liver and bacteria, a study utilizing this fact was made of the counting of a variety of tissues, both lyophilized and wet. Samples of about 50 mg were either

SAMPLE PREPARATION

1. Barium Carbonate (C^{14}). The inactive material was reagent grade. C^{14}-labeled material was prepared from a suitable mixture of sucrose and standardized benzene-carboxylic-C^{14} acid (*1*) by Van Slyke-Folch wet oxidation (*6*) followed by routine conversion of the evolved CO_2 to $BaCO_3$.

Particles fine enough for suspension counting were made from coarse $BaCO_3$ crystals by grinding for 3–5 min between the ground-glass surfaces in a small tissue homogenizer. Absolute alcohol was used to wet the particles during grinding. Toluene was used to rinse them into the counting bottle. Quantities were 0.5 ml of alcohol and 7.5 ml of toluene. This procedure for grinding and rinsing was used for the other materials except in a few cases that will be discussed.

2. Phenylalanine (C^{14}). C^{14}-labeled material of suitable specific activity was made by dilution of Tracerlab's 2-amino-3-phenylpropionic-1-C^{14} acid with inactive compound and precipitating it from methanol by neutralization of the hydrochloride with ammonium hydroxide. Assay of the product was obtained by Van Slyke-Folch wet oxidation, followed by direct plate counting of the derived $BaCO_3$ in an internal-sample flow counter. This counter was carefully standardized with some of the $BaCO_3$ mentioned previously.

3. Sodium acetate (H^3). A 1-ml portion of a 400 mg/ml aqueous solution of tritium-labeled sodium acetate was evaporated to dryness. Grinding and rinsing were done with 8 ml toluene. Alcohol was avoided because of its solvent power for sodium acetate.

4. Barium sulfate (S^{35}). Inactive material was prepared from commercial sodium sulfate, which was dissolved in water, acidified with hydrochloric acid, and treated with barium chloride to precipitate the desired product (*7*). Active material was prepared by adding a suitable dilution of $S^{35}O_4^{=}$ in HCl as supplied by Oak Ridge to the aqueous sodium sulfate before treatment with barium chloride. Quantitative yields were obtained.

5. Benzidinium sulfate (S^{35}). Inactive material was prepared from commercial sodium sulfate dissolved in an alcohol-water solution by adding benzidine hydrochloride to precipitate benzidinium sulfate (*8*). As above, for the preparation of the active material, a dilution of the Oak Ridge S^{35} in HCl was added to the solution of sodium sulfate before the precipitation.

6. Calcium oxalate (Ca^{45}). Inactive material was prepared by a standard procedure (*9*) from commercial calcium chloride. To make the labeled compound, a suitable dilution of Ca^{45} in HCl supplied by Oak Ridge was added to the above preparation before the final precipitation.

7. Calcium carbonate (Ca^{45}). Inert material was prepared by precipitation from an aqueous solution of calcium chloride to which was added a saturated solution of ammonium carbonate. The labeled compound was made by adding the dilution of Ca^{45} mentioned above before precipitation.

8. Tissues (C^{14}). A number of tissues, selected to give a wide range in color and composition, were taken from rats injected with C^{14}-nitrogen mustard. These were liver, spleen, testes, muscle and bone. Homogenates were prepared by freezing the tissue in liquid nitrogen and pulverizing while still frozen. Tissues from normal animals were used to provide inactive material.

Initial studies were made with dried material. This was obtained by lyophilizing aliquots of the tissue homogenates for 20 to 24 hr. The water collected from this drying was assayed for any activity that may have been lost from the tissue during the process. An insignificant amount of activity was found.

The usual grinding and rinsing procedures were used at first, but later work utilized the tissue homogenates directly. The sample was ground in 2 ml absolute alcohol and then rinsed into the counting bottle with 6 ml toluene.

9. Bacteria (C^{14}). *Lactobacillus arabinosus* cells were harvested from a 48-hr-old synthetic culture medium (*10*) and washed with saline and water. They were then lyophilized for 24 hr and yielded 260 mg inactive material.

Labeled bacteria were obtained as above, by growing the *Lactobacillus* in a synthetic culture medium containing C^{14}-nicotinic acid.

lyophilized and then suspended or suspended directly as wet tissue homogenate. Preparation of the C^{14}-homogenates and the suspensions is described under Sample Preparation.

An efficiency for each suspension was determined by the addition of internal standard and a recount. Since this efficiency is the same as the self-efficiency of the sample, the *f*-value being 1, dpm/mg were calculated from each suspension count. A comparison of the averaged results for each tissue when the suspension was prepared from wet and lyophilized material is shown in Table 2.

As mentioned previously, bottles of two sizes were used for this study. No difference in *f*-value was found between the two; this might be expected from consideration of the Beer-Lambert Law. With the same amount of suspended material, changing from the large bottle to the small would have the effect of increasing concentration while decreasing path length with absorption and scatter remaining the same. The small bottle numbers among its advantages: availability, cheapness, duplication of whiteness of glass, and ease of cleaning.

H^3. When 42.3 mg sodium acetate was suspended in an alcohol-free scintillator, the self-calibrated efficiency for the suspension was 3.1% and for the tritium internal standard 11.1%. This *f*-value of 0.28 is evidence for an expected large degree of self-absorption of the weak beta spectrum by the particles of the suspension because of their relatively large size compared with the range of the tritium beta particles.

S^{35} and Ca^{45}. The maximum beta energies of S^{35} (167 kev) and Ca^{45} (255 kev) are both greater than that of C^{14} (155 kev). One must then conclude from the previously mentioned C^{14} data that, with suitable grinding, the *f*-factors for S^{35} and Ca^{45} will be 1.0. Unfortunately, homogeneous internal standards for these isotopes were not available to check this.

Barium sulfate, benzidinium sulfate, calcium oxalate, and calcium carbonate gave very normal-appearing suspensions and seemed, from the Oak Ridge assays, to count with high efficiency, even when as much as 120 mg of material was suspended in the counting volume.

Settling Studies

An interesting facet of the behavior of these suspensions is their settling and the accompanying drop in counting rate. This drop is presumed to be due to the drift away from 100% geometry toward 50% geometry while settling to the bottom of the counting bottle. Figure 2 is a plot of the drop in counting rate vs. elapsed time for 20 mg of calcium oxalate in a typical experiment. At early times the drop is exponential and then levels off. Other concentrations and materials used behave this way too.

The slope of the exponential portion of the settling curve was determined for various concentrations of some of the suspensions. It was found to be reasonably independent of concentration, suggesting that the grinding process was reproducible. Average slope values were 3,640 sec for $BaCO_3$, 1,060

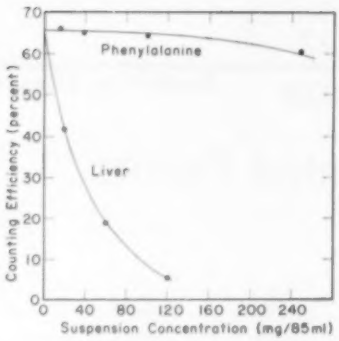

FIG. 3. Self-calibration and internal-standard counting curves for phenylalanine

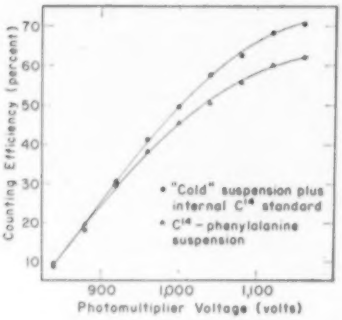
"Cold" suspension plus internal C14 standard
C14 – phenylalanine suspension
Counting Efficiency (percent)
Photomultiplier Voltage (volts)

FIG. 4. Effect of light scattering and absorption on scintillation counting of suspensions

TABLE 2—Counting Lyophilized and Wet Tissues

	Specific counting rate (dpm/mg)	
Tissue	*Lyophilized*	*Wet*
Testes	18.8 ± 0.6	19.0 ± 0.4
Liver	77.0 ± 4.1	82.0 ± 2.8
Muscle	23.7 ± 0.4	26.3 ± 0.5
Spleen	45.2 ± 2.2	44.5 ± 1.6
Sternum	19.8 ± 1.5	23.5 ± 0.8

TABLE 3—Comparison of Suspension Counting with Conventional

	Specific counting rate (dpm/mg wet weight)	
Tissue	*Suspension*	*Van Slyke-Folch*
Whole femur	18 ± 2	19 ± 2
Liver	37 ± 2	40 ± 3
Testes	7 ± 1	11 ± 1
Spleen	33 ± 2	44 ± 5
Thigh muscle	25 ± 1	26 ± 1

sec for phenylalanine, 530 sec for barium sulfate, 570 sec for calcium oxalate, and 310 sec for bacteria.

Self-Absorption

The suspended particle can be compared with the thin sample layer on a planchet. In the former case, there is 100% geometry between beta particles escaping the solid and the detecting medium (the liquid scintillator). But the latter case finds about 50% geometry the best realizable. A 1-mg/cm² $BaCO_3$ layer on a planchet produces a self-absorption factor of about 0.7 (*5*). This corresponds to an average thickness of about 2.3 μ and indicates very small effective particle size for the suspension with its smaller self-absorption. It was not established in this study whether the particles were actually as small as indicated or whether in wetting and partly permeating the particles the liquid scintillator may have reduced their absorbing dimensions.

The process of losing efficiency by self-absorption should act to degrade the beta spectrum such that the self-calibrated and internal-standard efficiencies will be the same for high energies and different for low energies. Figure 3 is a plot of counting efficiency vs. photomultiplier voltage for C^{14}-phenylalanine and nonradioactive phenylalanine with added C^{14}-benzoic acid internal standard. At low voltages only the high-energy part of the C^{14} spectrum was being counted and the curves are almost identical. With increasing voltage the curves diverge in the direction of decreasing *f* as low C^{14} energies rose above the lower discriminator and contributed to the counting efficiency.

Light Absorption

In earlier studies of homogeneous liquid scintillation counting of water samples, it was occasionally noticed on completing a count that the sample was very milky due to insufficient alcohol in the system. However, this opacity did not seem to interfere with counting.

Similarly, in this study considerable opacity due to large quantities of a white suspension did little to interfere with the passage of scintillations from solution to photomultipliers. Figure 4 demonstrates this point for phenylalanine.

The case of a colored suspension must be complicated by light absorption. Whereas, with a white suspension a photon will be reflected when striking a particle, the colored suspension must absorb it. The lower curve in Fig. 4 shows this for highly colored liver tissue.

C^{14}-Analyses of Tissue

The biologist needs a counting method for labeled animal tissues that is rapid, reproducible, and easy. The present method was compared in these respects with Van Slyke-Folch oxidation followed by $BaCO_3$ plate counting.

Five pooled tissue homogenates prepared as described on p. 50 were made of bone, muscle, liver, spleen, and testes taken from rats injected with C^{14}-nitrogen mustard. Triplicate aliquots of each homogenate were counted by each of the two methods and the averaged specific counting rates are compared in Table 3. The two methods are essentially in agreement for all cases.

The difference in operator time is significant. A rough estimate of operator time on one sample of tissue homogenate would be 100 min for the Van Slyke-Folch oxidation and $BaCO_3$ plate counting, 40 min for the scintillation counting of suspensions of lyophilized tissues, and 20 min for wet tissue homogenates. This estimate does not include time for the maintenance of equipment, etc., which probably would be about the same as operator time.

BIBLIOGRAPHY

1. D. L. Williams, F. N. Hayes, R. J. Kandel, W. H. Rogers, NUCLEONICS **14**, No. 1, 62 (1956)
2. F. N. Hayes, R. G. Gould, *Science* **117**, 480 (1953)
3. R. D. Hiebert, R. J. Watts, NUCLEONICS **11**, No. 12, 38 (1953)
4. J. R. Arnold, *Science* **119**, 115 (1954)
5. P. E. Yankwich, J. W. Weigl, *Science* **107**, 651 (1948)
6. D. D. Van Slyke, J. Folch, *J. Biol. Chem.* **136**, 509 (1940)
7. W. C. Pierce, E. L. Haenisch, "Quantitative Analysis," 3rd ed. p. 391 (John Wiley and Sons, Inc., New York, 1948)
8. J. B. Niederl, H. Baum, J. S. McCoy, J. A. Kuck, *Ind. Eng. Chem. Anal. Ed.* **12**, 428 (1940)
9. N. H. Furman, "Scott's Standard Methods of Chemical Analysis," 5th ed. vol. I, p. 210 (D. Van Nostrand Co., Inc., New York, 1939)
10. B. C. Johnson, "Methods of Vitamin Determination," p. 64 (Burgess Publishing Co., Minneapolis, 1948)

Coming Next Month

Scintillation Counting Today, a NUCLEONICS Special Report on the Fifth Scintillation Counter Symposium

Stress-Strain Curves for Reactor-Irradiated Plastics

By C. D. BOPP and O. SISMAN
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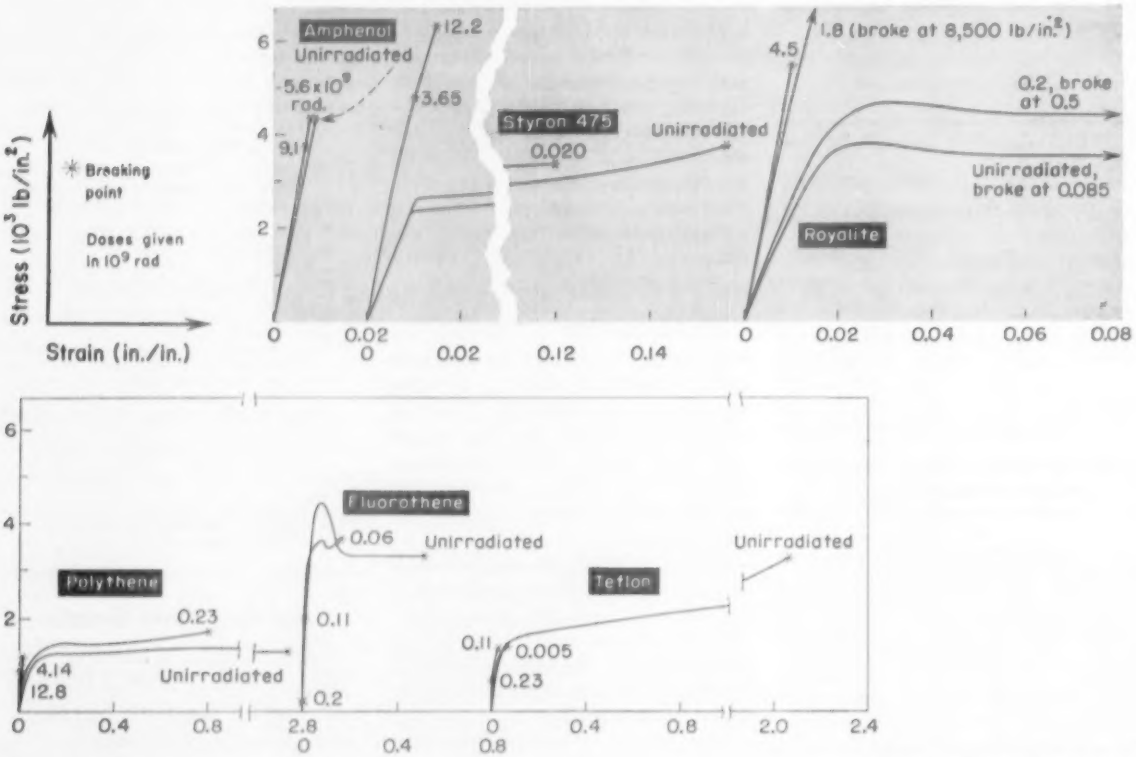
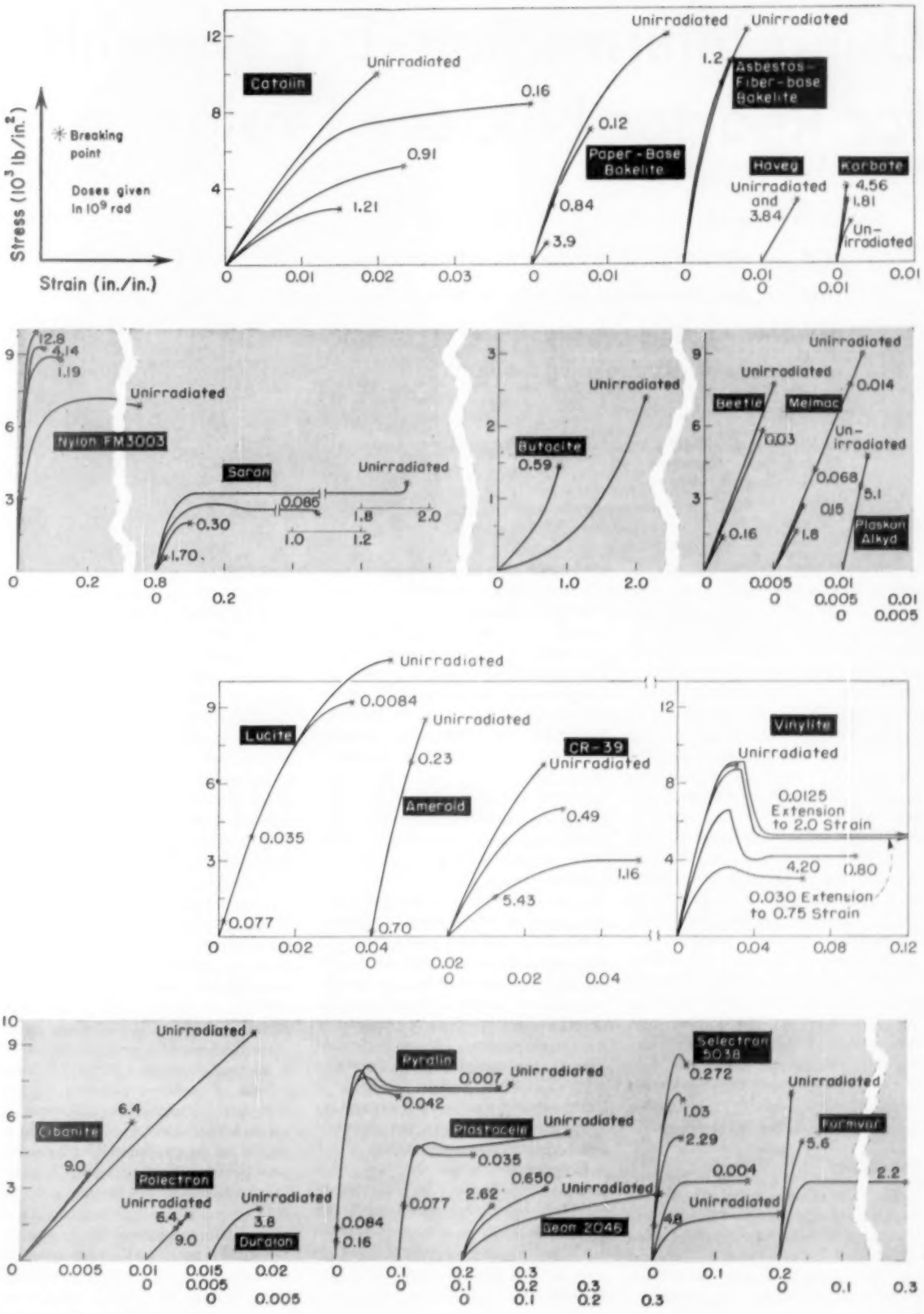
THESE DATA were taken on commercial plastics irradiated in the ORNL graphite reactor. A discussion has been given in ORNL-928, ORNL-1373, and NUCLEONICS (July '55, p. 28; Oct. '55, p. 51).

Tests were run on a Baldwin universal testing machine with recording extensiometer according to ASTM standard procedure D638-49T. Testing speed was 0.05 in./min to 0.02 strain and then increased to 0.20 in./min. Test specimens were ½ in. wide, 1/16–¼ in. thick, and strain (in./in.) was measured over a 2-in. gage length. Specimens were pretest conditioned to 25° C and 50% relative humidity.

The plastics included here are: Amphenol (unmodified polystyrene), Styron 475 (black-pigment-filled polystyrene), Royalite (styrene-acrylonitrile copolymer), Polythene (polyethylene), Fluorothene (polymonochlorotrifluoroethylene), Teflon (polytetrafluoroethylene), Catalin(unfilled phenol-formaldehyde plastic), paper-base and asbestos-fiber-base Bakelite (phenol-formaldehyde), Haveg (phenolic-bonded asbestos), Karbate (phenolic-bonded graphite), Nylon FM 3003 (polyamide), Saran (vinyl-vinylidene chloride polymer), Butacite (polyvinyl butyral), Beetle (urea formaldehyde polymer), Melmac (melamine formaldehyde polymer), Plaskon Alkyd (alkyd polyester), Lucite (polymethyl methacrylate), Ameroid (casein plastic), CR-39 (allyl diglycol carbonate polyester), Vinylite (vinyl chloride acetate polymer), Cibanite (aniline formaldehyde), Polectron (polyvinyl carbazole), Duralon (furan resin with asbestos and carbon black filler), Pyralin (cellulose nitrate), Plastacele (cellulose acetate)—other cellulosics behave similarly—Geon 2046 (polyvinyl chloride), Selectron 5038 (polyester), and Formvar (polyvinyl formal).




Stress (10^3 lb/in.^{2})
Strain (in./in.)
Breaking point
Doses given in 10^9 rad
Catalin
Unirradiated
0.16
0.91
1.21
Paper-Base Bakelite
Unirradiated
0.12
0.84
3.9
Asbestos-Fiber-base Bakelite
Unirradiated
1.2
Haveg
Unirradiated and 3.84
Karbate
4.56
1.81
Unirradiated
Nylon FM3003
12.8
4.14
1.19
Unirradiated
Saran
Unirradiated
0.086
0.30
1.70
1.8
2.0
1.0
1.2
Butacite
Unirradiated
0.59
Beetle
Unirradiated
0.03
0.16
Melmac
Unirradiated
0.014
0.068
0.15
1.8
Unirradiated
5.1
Plaskon Alkyd
Lucite
Unirradiated
0.0084
0.035
0.077
Amerold
Unirradiated
0.23
0.70
CR-39
Unirradiated
0.49
1.16
5.43
Vinylite
Unirradiated
0.0125 Extension to 2.0 Strain
4.20
0.80
0.030 Extension to 0.75 Strain
Cibanite
Unirradiated
6.4
9.0
Polectron
Unirradiated
5.4
9.0
Unirradiated
3.8
Duration
0.084
0.16
Ryralin
0.007
Unirradiated
0.042
Plastacele
Unirradiated
0.035
0.077
0.650
2.62
Unirradiated
Gear 2046
Selectron 5038
0.272
1.03
2.29
0.004
48
Unirradiated
Unirradiated
Formvar
5.6
2.2

Using Intermediate Experiments for Reactor Nuclear Design

Data for nuclear design of full-size reactors can be obtained by exponential-pile experiments. Since only a subcritical part of the core need be constructed, and there is no need for a reflector, shield, or cooling system, costs of the nuclear design of reactors are kept to a minimum. General principles and means of extrapolating the data to full-size reactors are described here

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IT BECAME theoretically possible to achieve a divergent nuclear chain reaction when it was established that fission of uranium is brought about by the capture of neutrons in uranium and that more neutrons are released per fission than are required to initiate the process (*1–4*). But practical production of such a chain reaction was not realized until the experiment of December 2, 1942, which was performed by E. Fermi and his collaborators (*5*).

In theoretical and experimental steps that led to the first divergent reaction, it was demonstrated that the reproduction factor and other constants could be measured with considerable accuracy for proposed nuclear reactors by the use of exponential experiments. An extended series of exponential experiments was begun in the early days of the project that brought about the first nuclear reactor (*5*). Numerous other exponential experiments have been performed since at atomic-energy installations interested in reactor development.

Pile Types

The value of exponential experiments for training engineers and scientists in reactor technology was realized even before such facilities were available on an unclassified basis (*6*). Two types of preliminary reactor structures are used to develop new reactors—critical assemblies and exponential piles.

Critical assemblies. A critical assembly, sometimes referred to as a zero-power reactor, is a reactor structure capable of operating with a divergent chain reaction; but it is intended to be operated at extremely low power with little or no radiation shielding. This type of assembly, which has the core and reflector arranged so that its neutron and nuclear properties duplicate those of the proposed reactor without elaborate heat-removal or coolant-circulation systems, provides means for making neutron-flux measurements and detailed determinations of the reactor constants. But its use requires extreme care in performing the experiments to be sure that the chain reaction does not diverge beyond safe limits. The original divergent chain reaction was essentially such an experiment. It was performed with the first nuclear reactor, known as CP-1 (*5*). Thus, a critical assembly or "zero-power" reactor can serve as an "intermediate pile" in the development of some proposed reactor.

Exponential pile. On the other hand, an exponential pile, which is considerably below the critical condition, is not operated as a divergent chain reaction. Only a fraction of a critical core is used and the reflector might be omitted for most of the experiment.

Sources

The first exponential experiments used radium-beryllium or similar sources of neutrons to provide the flux of neutrons to establish the steady-state conditions in the exponential piles (*5*). To speed up the taking of data, higher fluxes can be produced in the exponential experiments by using very large radium-beryllium sources, by using very intense reactor-activated antimony-beryllium photoneutron sources, or by employing a stably operating reactor to supply neutrons to the pedestal of the exponential pile.

The reactor as a neutron source for exponential experiments has a distinct advantage over the other sources since the intensity readily can be adjusted through a wide range without changing the harmonic components in the neutron flux supplied to the exponential pile.

On the basis of an extraneous source of neutrons, such as a vertical thermal column of an large operating reactor, one can assume that the neutron source is equivalent to a plane uniform source of approximately monoenergetic neutrons located at some distance below the top of the thermal column.

However, under differing conditions required for measurements in the exponential experiment, there must be discontinuities of one kind or another from the thermal column into the ex-

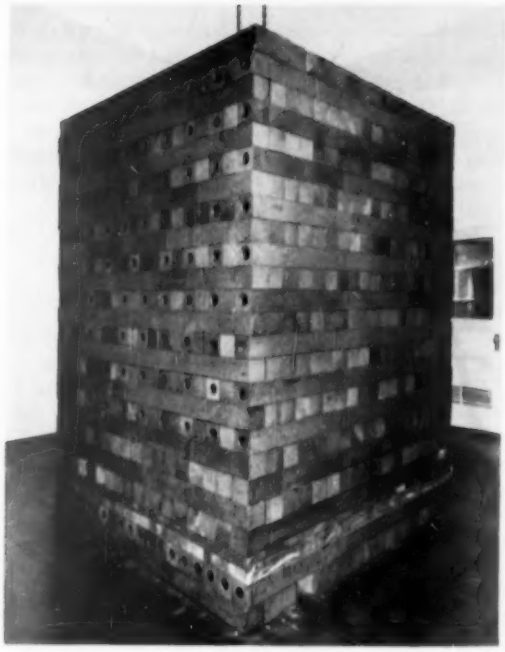

FIG. 1. Graphite structure of an exponential pile showing front and one side

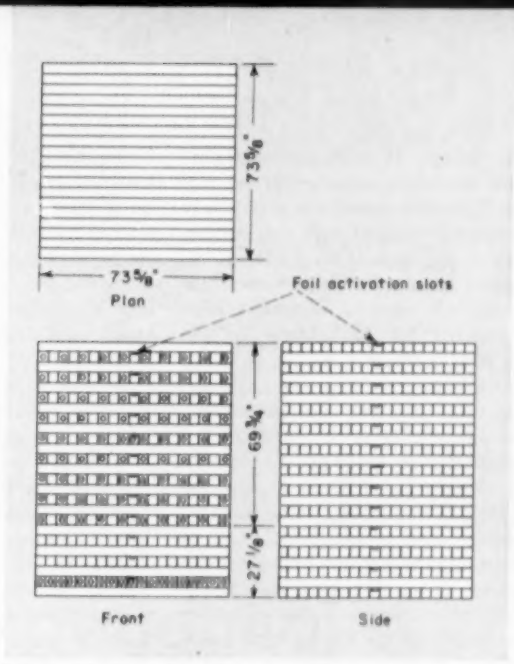

FIG. 2. Front, side, and plan views of the exponential pile

ponential pile. Such discontinuities cause changes in the progressive flux distribution through the thermal column and the exponential structure.

In general, the exponential pile is not arranged as an uninterrupted continuation of the thermal column, but is constructed as a pedestal placed on the thermal column with the exponential pile a continuation of the pedestal. The changes in geometrical shape and distribution of materials from the thermal column to the exponential structure distort the neutron flux. These distortions usually are referred to as the introduction of harmonics.

Harmonics

With an arrangement having the geometrical axes of the thermal column and the exponential pile coincident with the vertical, or Z axis, one finds for a given value of z that the flux distribution along a horizontal direction, such as the X-axis, is expressible by a fourier series written as a sum of products of cosine terms. If the distance from the effective source plane is sufficient, and no additional disturbances are introduced, the flux distribution can be represented by a simple cosine function. That is, only the fundamental term of the solution of the wave equation is needed to describe the flux distribution. For such a distribution, observations of the neutron flux along the Z-axis or along some other vertical line with fixed x and y values will show that the flux varies as the sinh $\gamma(c - z)$, or

$$\phi(z) = C'e^{-\gamma z}[1 - e^{-2\gamma(c-z)}]. \quad (1)$$

where c represents the vertical height of the exponential structure above the pedestal. When the value of z is considerably less than c

$$\phi(z) \simeq Ce^{-\gamma z} \quad (2)$$

and the observed neutron flux decreases in an approximately exponential manner. It is from this relation that the term "exponential experiment" has been derived (7).

The term c in Eq. 1 includes a distance (known as an extrapolation distance) from the actual upper boundary of the exponential pile at which the vertical flux distribution tends to zero.

Effects of harmonics on flux distribution. For a uniform exponential pile of very great dimensions placed on a source pedestal of correspondingly great dimensions, the neutron flux at any given value of z above the source plane would be essentially constant for all values of x and y very far from the boundaries of the pile. However, changes in the dimensions of the pile or the presence of discontinuities in the pile or the pedestal cause distortions of the neutron flux distribution.

Since an exponential pile is, from the basic concept of its usefulness, actually an intermediate pile having only a fraction of the dimensions required for a critical pile of the same core geometry, it follows that harmonics will be present in the flux distribution due to discontinuities and dimension changes from the pedestal to the exponential structure, and from the neutron-source region to the pedestal.

Harmonics also can be introduced that are dependent on the source arrangement. Small local disturbances in the flux will be brought about by the heterogeneous arrangements of fuel and moderator materials and other structural features incorporated in the exponential pile. If the core lattice spacing is uniform and small enough compared to the dimensions of the exponential pile, and if measurements of neutron flux are made at sufficient locations throughout the pile, it might be possible to describe the flux distribution so that small local fluctuations are disregarded. Under these conditions the neutron flux as a function of x, y, z is represented by

$$\phi(x, y, z) = \Sigma_m \Sigma_n A_{mn} \cos(m\pi x/a) \cos(n\pi y/a') \sinh \gamma_{mn}(c - z) \quad (3)$$

where a and a' are the x and y dimensions including extrapolation distances. From this it can be seen that the flux measured at points along the Z-axis depends on the harmonics present,

even though at sufficient distances below the upper boundary of the pile each harmonic varies in a very nearly exponential manner with the vertical position or value of z. Different relaxation lengths for the different harmonics will cause a departure from exponential for the change of the flux with position along the Z-axis.

In addition to this effect, further departure from the exponential relation occurs as observations of the flux are made nearer to the upper boundary. By evaluating the harmonic and end effects and eliminating these from the observed flux measurements, i.e., by applying harmonic and end-effect corrections to the flux data, the slope of $\ln \phi(z)$ vs. z will yield γ_{11}, or the relaxation length for the fundamental mode.

By using boundary and source conditions, the harmonic corrections are evaluated relatively easily so as to include the effects of the fundamental mode and the first few harmonics. Since the relaxation lengths fall off rapidly as the harmonics considered become higher, usually a good approximation to the corrected flux is obtained by accounting for only the third, or at most the fifth, harmonics. It then is possible to determine approximately γ_{11}, ($\gamma_{12} = \gamma_{21}$), γ_{22}, etc., to obtain the A_{mn} and the ratios of $(A_{12} + A_{21})/A_{11}$; A_{22}/A_{11}, etc., so that values $\phi_{11}(z)$ can be obtained, to which end-effect corrections are applied to yield a better value of γ_{11}. Improved values of a and a' are obtained by applying the harmonic corrections to the flux measurements made along the x and y directions for a fixed z. In turn, more accurate B_m^2 or B_m values are calculated since the material buckling B_m is rather simply related to the extrapolated dimensions and the relaxation length for an exponential pile with a desired fuel-bearing lattice. Ultimately, through the process of successive approximations, the values of a, a', γ_{11} and B_m are calculated to the accuracy desired.

By proper use of an exponential pile and by processes similar to those described, it also is possible to learn L^2, τ, k_∞, etc., for a reactor of similar core.

Extrapolating measurements to a full-sized reactor. The use of an exponential pile and techniques of some exponential experiments to supply information for reactor design are illustrated by considering the arrangement shown in Figs. 1 and 2. This rectangular parallelopiped exponential pile simulates a graphite-moderated reactor using aluminum-jacketed natural-uranium fuel rods centered in coaxial cooling channels. Small graphite rings slid over the 73⅝-in.-long fuel rods serve to position them properly for the exponential studies. An extra channel at the center of the lattice section provides means for inserting a strong absorber of neutrons to obtain data on a control rod's effect on flux.

With the pedestal section of the exponential pile arranged as shown, uranium rods placed in the channels below a cadmium curtain will supply fission neutrons for determining the age, τ, for the neutrons from fission energy to some other selected energy, such as to indium resonance or to thermal. With this arrangement it is possible to measure τ for the fission neutrons in graphite by activating foils of indium in the exponential pile while its channels contain graphite.

By filling the channels of the exponential pile with rods made from the proper alloy of mercury and lead, it is possible to simulate natural-uranium fuel rods without producing additional fission neutrons. Thus τ for the fission neutrons can be measured to represent that for a pile lattice containing natural uranium. Other techniques also accomplish this result.

With the cadmium curtain removed from the pedestal and the converter rods replaced by graphite, thermal neutrons can be supplied to the exponential pile. Foil activations made when all channels of the exponential section are filled with graphite are used to determine L^2, or L (the diffusion length) for thermal neutrons in the graphite of the simulated reactor. Again, foil activations can be made with the natural-uranium fuel rods in position to learn B_m^2 for the pile.

Since for a just-critical reactor the geometrical buckling, $B^2 = B_m^2$, it is possible to use the observations from an exponential experiment to calculate the critical dimensions of a reactor having the same core arrangement and geometrical design. If the reactor considered is cubical, these conditions are

$$B^2 = B_m^2 = 3(\pi/a)^2 \qquad (4)$$

By examining the relation

$$k_\infty/(1 + L^2B^2)(1 + \tau B^2) = 1 \qquad (5)$$

it is seen (7) that the constants L^2, τ, and B^2, which are obtainable from exponential experiments, can be used to determine the reproduction factor, k_∞, for a proposed core.

Additional information on relative thermal- and fast-neutron flux distributions in the exponential pile can be obtained from foil activations. By properly designing certain sections of the fuel rods and the surrounding moderating materials, small measuring foils can be distributed throughout these media. Data from these foils enable calculations for thermal utilization, disadvantage factor, etc., for the particular fuel, moderator, and structural-material lattice selected. Thus, it is apparent that with a sufficiently intense neutron source it is very practical to use exponential experiments for determining constants and characteristics of a reactor while it is still in the design stage (8).

BIBLIOGRAPHY

1. L. Meitner, O. R. Frisch, *Nature* **143**, 239 (1939)
2. H. von Halban, Jr., F. Joliot, L. Kowarski, *Nature* **143**, 470 (1939)
3. L. Szilard, W. H. Zinn, *Phys. Rev.* **55**, 799 (1939)
4. E. Fermi, H. L. Anderson, L. Szilard, *Phys. Rev.* **56**, 284 (1939)
5. E. Fermi, AECD-3269 (1952)
6. E. C. Campbell, L. D. Wyly, E. I. Howell, AECD-3169 (1950)
7. S. Glasstone, M. C. Edlund, "Elements of Nuclear Reactor Theory" (D. Van Nostrand Co., Inc., New York, 1952)
8. H. Dopchie, F. Leonard, M. Neve de Mevergnies, G. Tavernier, NUCLEONICS **14**, No. 3, 57 (1956)

Using Exponential Experiments

The exponential pile shown in this article was applied in a training course in reactor technology at Argonne National Laboratory by a group of 11 Belgian scientists selected by their government. Sponsored by the U. S. Atomic Energy Commission, the course ran April 28 to July 31, 1952.

Students were: Maurice D. E. D'Hont, Henri A. Dopchie, Pierre A. L. Erkes, Julien R. J. Goens, Louis J. H. E. Groven, Max Hoyaux, Emile H. A. Hubert, Marcel Neve de Mevergnies, Georges F. H. J. Stiennon, Emile Symon, and Guy C. Tavernier.

After completing the course, the group returned to Belgium and performed the experiment described on the next page. The data are being applied in Belgium's reactor program.

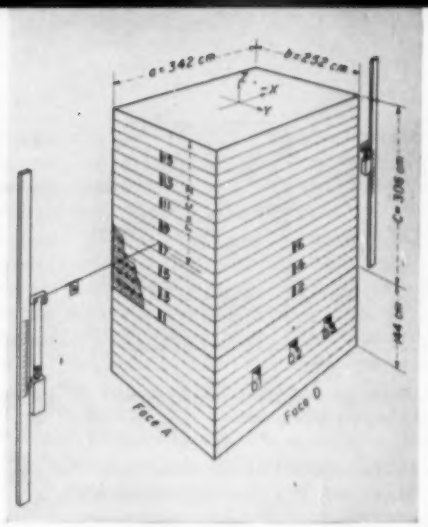

FIG. 1. General layout of exponential pile. The In foils are held in an aluminum holder and are pushed into position in the pile along a narrow slit in the graphite stack. Al holder's position is controlled by a Nylon wire stretched by two counterweights. Dimensions shown are geometrical. Constants a, b, and c used in calculations corrected for graphite extrapolation length and reflector effect are: a_{corr} = 345.92 cm, b_{corr} = 254.89 cm, c_{corr} = 307.46 cm

Conducting an Exponential Experiment with a Natural-U Graphite Lattice

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THE EXPONENTIAL PILE experiments described here were performed to obtain an experimental check on a theoretically computed value for the material buckling of a natural uranium-graphite lattice. They were performed by members of the staff of CEAN and Union Miniere in the nuclear physics laboratory of the Ecole Royale Militaire, Brussels, Belgium.

Equipment

The pile's general layout is shown in Fig. 1. The uranium slugs were 1 in. in diameter and 8 in. long. They were canned with aluminum $\frac{1}{32}$ in. thick on the side, with end caps $\frac{1}{8}$ in. thick. These slugs were located in 3.53-cm square channels, forming a square lattice of 18 cm pitch. The graphite density was 1.72 and the uranium density was 18.92.

A classical computation based on diffusion theory indicated that this lattice had a material buckling of about $1.3\text{–}1.5 \times 10^{-4}$ cm^{-2}, according to the way in which neutron leakage was taken into account and according to the values chosen for the various cross sections.

Pile size. The height of the exponential pile itself was such that the thermal flux decreased by about one decade in the 2.45-m counting region. We added 30 cm on the top to minimize the "end effect" and 30 cm between pile and pedestal to stabilize Cd ratio.

The pile's side dimensions were chosen so that the effective core volume would be a large fraction of the equivalent bare reactor—preferably between $\frac{1}{4}$ and $\frac{1}{2}$. Taking into account the 18-cm pitch and the length of our uranium rods, we adopted a 3.42×2.52-m cross section.

The over-all effective core volume was 31 m^3, $\frac{1}{5}$ the volume of the bare critical pile with a rectangular cross section. This is a somewhat more favorable ratio than in the original Fermi experiment (*1*), where the volume ratio of the critical bare pile to the exponential pile was about 11. The agreement between the exponential and critical experiments was about 7% in the Fermi experiment.

The available free space in the laboratory was about $11 \times 11 \times 15$ m. No interference from neutron scattering by the walls was detected. Loaded with uranium and covered with cadmium, the pile weighed about 75 tons. This load rested uniformly on 40 m^2.

Neutron sources. The Ra-Be neutron sources were collected in four groups. Their net yield was 8.8×10^7 n/sec for 7.5 curies of Ra. These sources could be located either together at the center of the pile or in four groups symmetrically located in various points in the pile's source plane.

The sources were located in three different patterns as shown in Fig. 2. To change from one pattern to another, three channels D_1, D_2 and D_3 were provided on the pedestal's fifth level. The sources were in holes made in the graphite drawers filling those channels.

Since the energy spectrum of the neutrons was rather hard, the pedestal of the exponential pile had to be high

FIG. 2. Source layer of pedestal, showing the three different source distributions. Pattern 2 gives smallest harmonic corrections and highest counting rates

enough to give the primary neutrons a large cadmium ratio.

Detectors. The detectors were indium foils of 25 mm diameter and 0.2 mm nominal thickness. Around that thickness, the In sensitivity curve has a rather flat maximum. With this foil area, we had good statistical accuracy in reasonable counting time (4–10 min).

The graphite was available in the form of blocks in which the grooves forming the uranium channels already were machined. But we wished to avoid, as far as possible, any further machining of the blocks. This led us to reject the technique of holding the detectors in shallow drawers (usually called stringers) machined in graphite.

The detectors were held by aluminum holders slipped into the graphite stack along 1.5-mm slits going through the pile as shown in Fig. 1. The slits perpendicular to the uranium channels (at the even levels) were not in the middle plane, but 9 cm from it. Because of the pile's large dimensions, the errors so introduced are very small. Nevertheless, this fact was taken into account in the mathematical analysis of the experiment. The position of the aluminum holder is controlled by a Nylon thread stretched from both sides of the pile by two counterweights.

The foil holders used for even layers were of different design than those used for odd layers. The flux depressions for these two types differed by about 1% and the measurements were corrected accordingly.

This method of detector positioning was quite successful; accuracy was about 1 mm. No great error can be expected from neutron leakage through such a thin slit in the pile. This was checked experimentally by measuring carefully, at different locations, the neutron current leaking out of an area including a channel. There was a strong increase of the leakage at the channel itself, but no extra leakage could be detected at the detector slit.

About 100 flux measurements were made for each experiment. Each measurement used a new foil. The 400 foils available weighed 0.550–0.650 gm.

Careful intercalibration of the foils was made by measuring the activity of 17 foils with weights of 0.350–0.970 gm. It was found that all the activity could be reduced to that of a foil of a standard weight, $W_0 = 0.612$ gm, by multiplying by a correction factor

$$f = (4.31502\ W - 6.09208\ W^2 + 2.7962\ W^3)^{-1}$$

where W = weight of the foil in gm. This function has a very flat maximum at W_0. Several hundred foils had a correction of less than 1%.

The intercalibration formula was found to be practically the same for our four counting equipments, although it cannot be expected to be independent of the various counting efficiencies. The Cd ratio in all these measurements was about 6.3.

Counting equipment. Each activated foil was measured by four independent counters. Two of these were made of Victoreen 1-B-85 G-M counters and two were Ekco scintillation counters. The counters and some auxiliary apparatus were located in an underground counting room about 25 m from the pile.

A reasonable multiplicity of counting apparatus offers several advantages, of which the most important are: (a) a continuous check of the behavior of each counter is given by the ratio of the counting rates of a foil at each counter; (b) if any one of the counters has to be stopped for a few hours for repairs, the experiment can be continued with only a small loss of statistical accuracy.

G-M and scintillation counters are complementary instruments. Indeed, the large high-voltage and gain sensitivities of scintillation counters are compensated by their very small effective dead-time and a good dynamic response. These have to be compared with the good plateau of G-M counters and the disadvantage of a large dead-time and a small dynamic range. In our set-up, the G-M and scintillation counters had an over-all efficiency of the same order of magnitude, and also had the same background.

Planning the Experiments

The accuracy of the experiment depends highly on the care with which the planning has been made and followed. These conditions should be fulfilled:

1. The indium detectors should be irradiated for at least four half-lives to minimize the correction for saturation activity. But the irradiation should not be so long as to reduce the long-half-life activation.

2. Only one detector should be irradiated in any given channel at a time. The full loading of the pile then is complete with about eight detectors in various longitudinal and transversal channels at coordinate points such that one detector's shadow effect on another is negligible. Experiments were carried out to check this point.

3. From the end of the irradiation until the counting is finished, the various timings should be the same for all foils, so that the exact knowledge of the half-life of In is not required in the analysis. After some practice had been gained, the time jitter around the nominal time of extraction of the detector was about 2 sec, i.e., negligible.

4. Any experiment is carried out nonstop with four teams of 6 hours a day. The over-all stability of the equipment is much improved by this method.

Irradiations

Foils were irradiated at different levels in the central planes of the pile. Measurements were made at the central vertical axis of the pile and also at five points on each side of the X axis. Since the channels were parallel to the x direction, the 11 points of measurements could be distributed uniformly so that the extrapolated length a was divided into 12 equal intervals.

In the y direction, the heterogeneous nature of our reactor required that the detectors be spaced by an integral multiple of the pitch. Thus, we selected 11 points for measurements. These were 18 cm apart, but did not divide b in equal intervals.

Measurements were made according to the following scheme:

1. Levels 3, 5, 7 and 9 (along X axis) and levels 4, 6 and 8 (along Y axis); 11 points were measured, some were repeated several times to check the overall stability and to improve the accuracy. No measurement was made at levels 1 and 2, because the Cd ratio was not constant there.

2. Levels 11, 13 and 15; at least 3 or 4 repeated measurements were made at the central point ($x = y = 0$). It was thought that the activity would be too low to have accurate harmonic analysis at these levels by measuring 11 points as we did for lower levels. But it appears that the final analysis would have been much easier had we done so.

Experiments Performed

Three experiments were made to measure B^2, corresponding to the three different locations of the sources as shown in Fig. 2. We thought it was of great interest to measure experimentally the relative harmonic contributions to the different distributions.

Except for a small fraction of rejected data, the ratio of the activity measured with the second scintillation counter and the two G-M counters, to that measured by first scintillation counter, had a standard deviation of 0.14%. No significant difference could be found in these ratios by collecting separately foils strongly and weakly activated. This partial check on the linearity of different counting units is important in an exponential experiment. These mean ratios were: 0.651, 0.886, 0.800, i.e., of the same order of magnitude. For final analysis, all data were collected in one group by taking the arithmetic mean of the four corrected countings.

The data along the central axis is shown on Fig. 3 and that along X in level 3 on Fig. 4. The order of magnitude of the counting rate can be seen.

The activation of indium detectors by spontaneous fission neutrons was measured at many points in the pile when all the sources were removed. The activity was low enough for the results to be fitted quite well, for levels 3 to 15, by

$$A_s = 0.785 \cos(\pi x/a) \cos(\pi y/b) \cos(\pi z/H)$$

The origin of the z axis is 14 cm above level 6 and $H = 195.5$ cm. Because of the large yield of the Ra-Be sources we used, this neutron background was relatively very small, so that even a 10% error on the above expression would not change the final result by more than 0.1%.

Theoretical Analysis

We chose our coordinates as shown on Fig. 1. In the z direction, the practical variable is $r = c - z$, whose origin is at the effective extrapolated height.

As shown by W. H. McCorkle (*3*), the neutron flux can be represented by

$$\phi(x,y,r) = \Sigma_{m,n} A_{mn} \cos(m\pi x/a) \cos(n\pi y/b) \sinh \gamma_{mn} r \quad (1)$$

The A_{mn} are the amplitudes of the various harmonics. The γ_{mn} are related to each other by the material buckling B^2 of the reactor and the geometrical factors G_i^2 such as $(m\pi/a)^2$, . . .

$$B_e^2 = \xi G_{mx}^2 + G_{ny}^2 - \gamma_{mn}^2 \quad (2)$$

Where B_e^2 = the buckling perpendicular to the channels. But Eq. 2 differs from the accepted one because of the coefficient of anisotropy, which takes into account the leakage of neutrons by the air channels in the x direction. This coefficient introduces an anisotropy in the buckling evaluated by employing a theoretical expression given by Behrens (*4*) for the diffusion length parallel and perpendicular to the channels. However, in practice, the effect is generally negligible.

The parallel component is given by

$$B_a^2 = (1/\xi) B_e^2 \quad (3)$$

On any one level along the y or x axis, $x = 0$ or $y = 0$ and r is constant, so that we can write Eq. 1 as

$$\begin{aligned}\phi(x,r) &= (A_{11} \sinh \gamma_{11} r + A_{13} \sinh \gamma_{13} r + A_{15} \sinh \gamma_{15} r + \cdots) \cos(\pi x/a) + (A_{31} \sinh \gamma_{31} r + A_{33} \sinh \gamma_{33} r + \ldots) \cos(3\pi x/a) + \ldots \\ &= b_1 \cos(\pi x/a) + b_3 \cos(3\pi x/a) + \ldots \quad (4)\end{aligned}$$

at the odd levels; and at the even levels

$$\begin{aligned}\phi(y,r) &= (A_{11} \sinh \gamma_{11} r + A_{31} \sinh \gamma_{31} r + A_{51} \sinh \gamma_{51} r + \cdots) \cos(\pi y/b) + (A_{13} \sinh \gamma_{13} r + A_{33} \sinh \gamma_{33} r + \cdots) \cos(3\pi y/b) + \cdots \\ &= a_1 \cos(\pi y/b) + a_3 \cos(3\pi y/b) + \cdots \quad (5)\end{aligned}$$

A least-square analysis can split the data into harmonics b_i for the odd levels and a_i for the even levels.

In practice, as the flux is measured at a finite number of points, this series must be limited to a finite number of terms. If the flux measurements were perfectly accurate, this could be done in such a way that the number of unknown harmonic coefficients was equal to the number of measurements.

Actually, as the measurements are subject to statistical errors, one has to limit the series to a smaller number of terms and to determine the corresponding unknown coefficients by the least-squares method.

But there is no easy criterion to decide *a priori* to how many terms the series should be limited in each practical case. Thus, we decided to try three different sets of harmonics, as follows:

1. We take into account all the measurements (even and odd levels) and we consider only A_{11}, A_{13}, A_{31}, A_{33}, and A_{51}

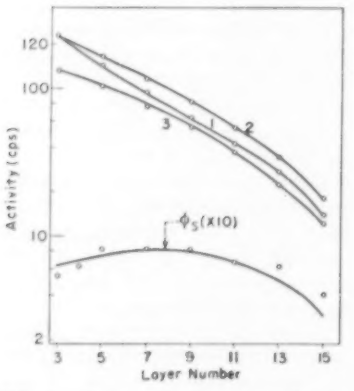

FIG. 3. Flux distribution along Z axis. Curves 1, 2, and 3 correspond to the three different source distributions shown in Fig. 2. ϕ_s is the spontaneous fission neutron distribution (multiplied by 10)

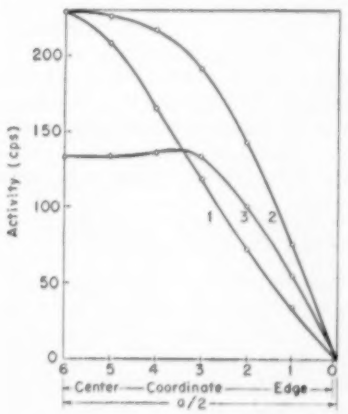

FIG. 4. Transverse flux distribution at level No. 3. The three curves correspond to the three different source distributions

as significantly different from zero.

2. As there are some slight differences of technique between the measurements made at the odd levels and the even ones, we take into account only the results at the odd levels and we consider the five harmonics A_{11}, A_{13}, A_{15}, A_{31}, and A_{33} to be computed directly by the least-squares method.

3. With the data from the odd levels only, we consider the six harmonics A_{11}, A_{13}, A_{15}, A_{31}, A_{33}, and A_{35}, but the ratios A_{15}/A_{13} and A_{35}/A_{31} are given by the classical diffusion theory, so that only four unknowns are to be obtained by least-squares.

In each case, the method of computation is quite similar. For instance, in the second method we formally proceed according to the following steps.

From a trial value of B^2 we work out, for each level r, an attenuation coefficient $\sinh \gamma_{mn} r$. On each odd level from 3 to 9, the harmonic analysis gives us b_1 and b_2, i.e.,

$$b_{1i} = A_{11} \sinh \gamma_{11} r_i + A_{13} \sinh \gamma_{13} r_i + A_{15} \sinh \gamma_{15} r_i$$

$$b_{2i} = A_{31} \sinh \gamma_{31} r_i + A_{33} \sinh \gamma_{33} r_i$$

and on each level 11, 13, 15 at points $x = y = 0$,

$$\phi = A_{11} \sinh \gamma_{11} r_i + A_{13} \sinh \gamma_{13} r_i + A_{15} \sinh \gamma_{15} r_i + A_{31} \sinh \gamma_{31} r_i + A_{33} \sinh \gamma_{33} r_i$$

so that we have 11 simultaneous equations to be solved by least-square analysis for the unknown harmonics A_{ij}. The various harmonic terms $A_{mn} \sinh \gamma_{mn} r$ (for $mn \neq 11$) are then worked out and subtracted, respectively, from b_{1i} or ϕ_i to give seven values Y_i that should satisfy

$$Y_i = A_{11} \sinh \gamma_{11} r_i \qquad (6)$$

A least-square analysis gives the best value for γ_{11} and A_{11}, from which we compute a new value of B^2.

The normal procedure would be to start the analysis again with this new value, and to repeat this iteration until the relative increase $\Delta B^2/B^2$ becomes negligible. But we found this procedure too slow. Instead, we make two complete analyses for two trial values of B^2, one below and the other above the expected true value of B^2. From the relative values of the + and $-\Delta B^2/B^2$ so obtained, we infer a better approximation for B^2. We then can start again with two new values bracketing this approximation. In other words, the value of B^2 is obtained by interpolation on the curve $\Delta B^2/B^2$ versus B^2. We found that this curve is quite linear for $\Delta B^2/B^2 < 0.03$ but that its slope is about 25 times less for the second method than it is for the two others.

TABLE 1—Pressure Corrections for B^2

Experiment	*Mean pressure (cm Hg)*	$10^6 B^2$ (cm^{-2})
1	75.797	−0.02
2	73.046	−0.34
3	75.561	−0.05

Correction for Reflector

On each side of the b length, and on top of the pile, there was one more half-layer of graphite than required by the number of uranium channels. One-group-reflector theory was applied to these regions. For such a thin reflector, the effective extrapolated lengths are nearly the same as the extrapolated lengths of the graphite.

Correction for Pressure

During each of the three experiments, the atmospheric pressure was stable, but important differences were noted from one experiment to another. All data were reduced to 760 mm Hg with a correction formula obtained by differentiating $B^2 = (k - 1)/M^2$ with respect to the pressure P and keeping in mind the fact that we have air in the channels and in the pores of the graphite. The final formula is

$$\frac{dB^2}{dP} = -\frac{(k - B^2L^2f)(1 - f)}{M^2 \Sigma_{g_a}} (V_{A1} + V_{A2}) \sigma_a \frac{dN}{dP}$$

where: V_{A1} = volume of air in the channel, per cm of cell; V_{A2} = volume of air in the graphite, per cm of cell; σ_a = absorption cross-section of nitrogen; N = number of nitrogen atoms in 1 cm³ of air; and the other symbols have their usual significance. B^2 corrections are in Table 1.

Results

Our results are shown in Table 2. The ξ factor is computed according to Behren's theory (4), which gives $\xi = 1.0091$. And the mean scalar buckling is given by

$$\frac{1}{B^2} = \frac{2}{3}\frac{1}{B_e^2} + \frac{1}{3}\frac{1}{B_a^2}$$

TABLE 2—Results of Experiment

		Method of analysis 1	2	3
$10^6 B_e^2$	Exp. no. 1	138.3	145.2	137.7
	Exp. no. 2	137.8	144.7	139.5
	Exp. no. 3	140.1	144.7	140.4
Mean $10^6 B_e^2$		138.7	144.9	139.2
Mean $10^6 B^2$		138.3	144.4	138.8

Best Ra-Be Arrangement

In the first experiment, all sources were concentrated at the center. The harmonics were positive and represented about 20% of the 11 component at level 3. In the second experiment (Fig. 2), the algebraic sum of the higher harmonics is of the order of −5% of the 11 component at level 3. In the third experiment, the 31 component increases to a high negative value and the 13 component becomes very small. The harmonics build up to −20% of the fundamental. This general trend is clearly seen on Figs. 3 and 4. As could be expected, experiment 2 is the most satisfactory from the point of view of the harmonic corrections.

We think that, in a general way, it is difficult to choose with absolute confidence between the three methods of analysis. However, in this particular case: (a) method 1 gives doubtful results because the factor by which even level measurements had to be multiplied (to take into account the difference in detector-holders and the 9-cm shift), could not be determined with great accuracy; (b) method 2 gives doubtful results because the values found, for some harmonics, are inconsistent. No such objection can be made to method 3. Thus, we conclude that the results given by this method are the most valid of all.

But, in any case, it should be noted that our results, both for individual and mean values, are very close to each other and, in fact, well inside the 7% limit of error generally accepted for exponential experiments.

BIBLIOGRAPHY

1. E. Fermi, AECD-3269
2. D. J. Behrens, AERE-T/R-629 (Atomic Energy Research Establishment, Harwell, Eng., 1951)
3. W. H. McCorkle, NUCLEONICS **14**, No. 3, 54 (1956)
4. D. J. Behrens, *Proc. Phys. Soc.*, **A62**, 607 (1949)

Handling Alpha-Active, Pyrophoric Materials

1—What is the Best Approach?

Fabricating plutonium—the most difficult to handle of these metals—is complicated by combustible fine particles and sometimes by intense gamma and beta activities. Hazard evaluation points to several handling methods

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POWDER METALLURGY, as applied to fuel fabrication for nuclear reactors (*1*), emphasizes the problem of handling high-intensity alpha emitters that may also be pyrophoric and gamma active. Glovebox and manipulator techniques for handling these materials have been studied at Argonne particularly for application in its plutonium metallurgy research laboratory and fuel-fabrication facility.

In this series of articles, we indicate current lines of reasoning, decisions made in designing and constructing facilities for handling large amounts of high-intensity alpha emitters at ANL, and experience in operating one of these facilities. Special reference will be made to handling plutonium, since this alpha emitter and its alloys are our main concern at the ANL metallurgy division because of their importance as fuels for power-breeder reactors (*2*). As can be seen from the discussion of relative health hazards (p. 63), and in view of the pyrophoric nature of plutonium and some of its alloys, any of the pure alpha emitters can be handled safely by methods that are suitable for plutonium.

Parts 2 and 3
of this series will discuss "Design and Construction of Gloveboxes" and "Ventilation and Atmosphere Control of Gloveboxes."

Glovebox Systems

Existing glovebox systems for handling plutonium differ considerably in their design depending upon whether they are for research or production, upon equipment they must contain, upon the quantity of material used and its specific activity, upon the policy and requirements of the establishment where they are used, and upon the philosophy and background of the designers.

There has been considerable experience with glovebox systems using once-through air ventilation in enclosures of questionable tightness and techniques, such as open-air transfers, that permit occasional and sometimes serious contamination of the room. Low-cost construction, greater flexibility, and faster work are offset by the sacrifice in safety and by the time spent in monitoring and in cleanup. There is also a greater reliance on the human element.

On the other hand, a philosophy of minimizing the formation of fine plutonium particles, of never exposing bare contaminated materials outside the glovebox system, and of never purposely opening the contaminated system to the room leads to a closed leak-tight system with an inert atmosphere and very special transfer and maintenance techniques. Such an approach appears to sacrifice some flexibility and speed of operation, but this is mostly because techniques have not been fully developed.

The British have described two methods of assuring conditions sufficient to contain safely and work with large quantities of dry alpha-active materials in a protective atmosphere with less concern for glovebox tightness (*3*). One approach consists of essentially a glovebox within a glovebox with the gloves of the outer box inside the gloves of the inner box and with the pressure of the outer box lower than that of the inner box or of the room. Loss of feel because of the double gloves and difficulties in changing gloves on the inner box make this approach impractical. A variation that has been used with some success provides for an intermedi-

*L. R. Kelman and W. D. Wilkinson were concerned with the ANL Plutonium Metallurgy Research Laboratory, A. B. Shuck with the ANL fuel fabrication facility, and R. C. Goertz with the handling of gamma emitters.

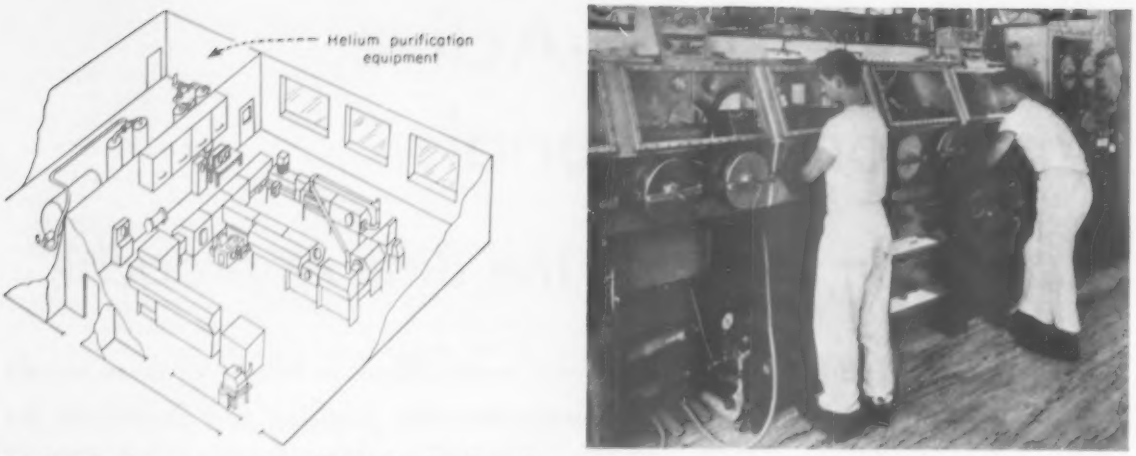


FIG. 1. Glovebox arrangement in ANL Plutonium Metallurgy Research Laboratory. Space limitations (there is actually less aisle room than indicated) precluded transfer corridor—objects are passed from glove to glove. Transfer doors to room permit replacing equipment by plastic-pouch technique. Helium atmosphere is circulated in closed system through copper plumbing to regenerative-type adsorption purification system. Safety exhaust system acts automatically if leak develops or normal controls do not function. Boxes can be isolated to avoid shutdown of entire system

ate chamber between the inner and outer gloveboxes that can be continuously evacuated to a pressure lower than either box and through which a single glove can pass. This approach loses some of the working reach of the gloved hand. The gloves are used only for assembly of apparatus where the experiment is carried out by remote operation with the gloves removed and the glove ports sealed.

ANL Plutonium Metallurgy Research Laboratory. The only existing large plutonium-handling facility that has used successfully a closed inert atmosphere with leak-tight gloveboxes is the Plutonium Metallurgy Research Laboratory at ANL.

Operation of this facility for 1½ yr has demonstrated the feasibility of this approach and has pointed up several real advantages, especially in safety. During this time, no plutonium contamination has escaped from the boxes; thus, personnel have never been exposed to high air counts—to our knowledge, an unmatched record for work in this field. This approach appears to us to come closest to the requirements of the plutonium powder metallurgist.

The main purpose of this laboratory is to develop and study fuel-element alloys containing plutonium or other alpha emitters. The laboratory is fairly complete and diversified. It is equipped to study phase diagrams, having facilities for melting and casting as well as thermal analysis, dilatometry, and metallography. Equipment is available to study workability (rolling, pressing, extruding), machinability, heat treatability, and corrosion characteristics. It is also equipped to study tensile and hardness properties, expansion characteristics, and thermal and electrical conductivity. In addition, the laboratory has made numerous test pieces for exponential, critical, and irradiation experiments.

The Research Laboratory design philosophy was governed by several restricting factors. The available room was only 27 × 30 ft in a chemistry building (*4*). Special facilities that require low air counts were located in adjacent rooms. ANL is located near populous areas, which means extreme controls of the amount of contamination in waste gases. Since this was to be a research facility, it seemed desirable to study the advantages and disadvantages of an inert atmosphere from the point of view of maintenance and cost, the influence on metallurgical research, and the safety aspects. Also it was desired to study various approaches to glovebox and accessory construction as well as to operating techniques with a view toward applying the information to the design of a much larger facility for fabricating fuel elements.

Stainless-steel gloveboxes with specially designed gasket flanges for windows and interbox connections were

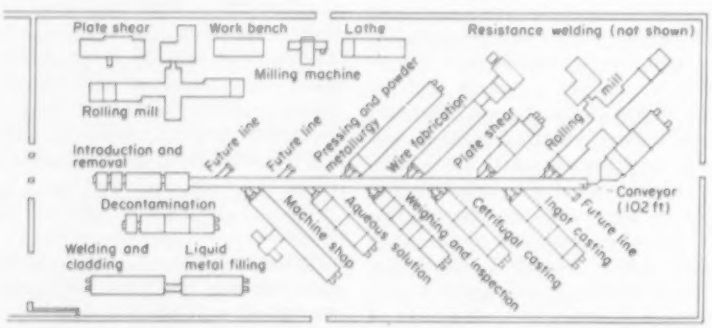


FIG. 2. Gloveboxes in fuel-fabrication facility. Conveyor and branches are closed system and eliminate air transfer of materials between operations. Gas-tight valves separate branch gloveboxes from conveyor. Every item entering line is assumed immediately contaminated beyond tolerance. Gloveboxes not attached to conveyor will be kept at low-level contamination to prevent transfer of contamination outside of box. Auxiliary equipment outside of primary gloveboxes —vacuum and hydraulic systems, mechanical drive assemblies and seals—that may be contaminated by gasket or joint failure will be housed in hood enclosures

developed to achieve the desired helium leak tightness. Tightness to a helium-sensitive mass-spectrometer leak detector was obtained only after much painstaking and time-consuming effort. Figure 1 shows the "E" arrangement of these gloveboxes.

ANL fuel-fabrication facility. A versatile large-scale metallurgical fabricating facility for fuel-element work is being constructed at ANL (*5*). It was designed with much the same safety and tightness considerations as the Research Laboratory. However, the gloveboxes are much larger with much more complex gasketing problems so that it will be impractical to achieve helium-mass-spectrometer leak tightness in a reasonable length of time. By comparison with most large-scale glove-box facilities, this facility will be essentially "tight." Its air-helium ventilation system will be described in the last article of this series.

The fabrication facility, which will be completed early in 1957, will include equipment for melting and casting ingots and shapes, centrifugal casting, rolling, shearing, wire and foil fabrication, press work, machining, electrocleaning, plating, polishing, weighing, and inspection of unclad materials; for welding alpha-emitting materials into nonradioactive jackets; and for roll-bonding, shearing, machining, and welding the jackets onto nonradioactive core materials. It also will include facilities for handling alkali metals and liquid-metal bonding media.

Because of the large equipment and the attendant high costs of modification and enclosure, approaches other than the standard glovebox were given careful consideration. The glovebox approach was finally decided upon mainly because there was more experience to draw from, and it appeared to offer the maximum process flexibility.

Special aluminum gloveboxes of flexible modular design were developed to house the small and large equipment. Figure 2 shows the arrangement.

Minimizing Dust Hazards

In work with oxides, hydrides, or metal powders, the equipment should be designed to eliminate or control dusting wherever possible. At ANL we have gone to great pains to minimize the fine-particle problem. As demonstrated by the complete freedom of our laboratory from contamination, we have been well rewarded for our trouble.

It is important to keep the amounts of plutonium-bearing waste to a minimum in any one place. Small chips, powder, and saw fines are brushed up and put into gas-tight containers as soon as possible after they have been produced. In addition a portable vacuum cleaner is used to clean the more inaccessible places in the gloveboxes. The material collected in these ways is removed from the system in small amounts and given to the proper agency for recovery, storage or waste disposal.

Inert atmosphere. An important method of minimizing fine-particle formation is to maintain an inert atmosphere in the glovebox system so as to minimize oxidation and compound formation. These materials are brittle and tend to form extremely fine, easily air-borne particles. Minimizing the amount of fine particles also simplifies the filtering problem where the gases are circulating. There are also obvious metallurgical advantages in reducing oxide-film formation on metallic plutonium and its alloys.

Studies of titanium, zirconium, thorium, and uranium, metals that might be expected to behave somewhat like plutonium, reveal that up to 12.5% air in helium can be tolerated without fire or explosion hazards (*6*). However, much better purity is required to prevent the oxidation that results in objectionable fine particles. If the technical advantages of oxide-free surfaces are of interest, impurity levels in the range of a few parts per million are desired.

Moisture. Moisture is the impurity of major concern in plutonium glovebox work. It has been reported that the presence of even a small amount of oxygen in the helium inhibits reaction with moisture, presumably by the formation of an oxide-film barrier. Where the oxygen is essentially absent, there is evidence that the moisture reacts with the plutonium to form an extremely reactive hydride that will catch fire on subsequent exposure to an oxidizing medium such as air. Plutonium hydride is considered more pyrophoric than many other hazardous metal powders and hydrides (*7*).

The difficulty of constructing and maintaining a glovebox system tight enough to contain helium and to keep it pure has turned out to be a blessing in disguise. Experience has proved that such a system is plutonium leak tight. Leaks that develop in such places as gloves often can be detected with a mass-spectrometer leak detector before contamination leaks out of the system. However, the effort necessary to achieve and maintain such tightness should not be minimized. Also, problems of purifying and circulating helium are more complex than the problems of ventilating the more standard air boxes. However, we feel that for many applications, and certainly working with metal powder is one of them, the technological and safety advantages of inert atmospheres far outweigh the disadvantages.

Philosophy and Rules of Handling Alpha Emitters

Health hazards, detection, and disposal of radioactive materials have been discussed extensively in the literature (*2, 8–11*). General information on working at relatively low-level alpha activities is available from several recent symposia (*3, 4*). Safeguards against external irradiation are relatively well understood so that safe handling practices of major concern are governed mainly by the toxicity considerations.

The extreme biological damage of alpha emitters can be attributed to their small penetrating power—45 microns in tissue (*2*)—since the entire energy is dissipated in the tissues immediately surrounding the point of deposition. Since there is still much to learn about permissible exposure levels, available information must be regarded with caution and safety factors used wherever possible (*11*). A safe practice worth striving for is to permit no radioactive material, especially one of the bone-seeking alpha emitters, to enter the body.

The alpha-emitting elements of present metallurgical interest include thorium, uranium (U^{233}, U^{235}, U^{238}, and normal uranium), radium, polonium, and plutonium. The radioactivities of these elements differ both in intensity and in energy. Thorium and normal uranium may be handled with about the same degree of caution as is

used in handling any chemically toxic or pyrophoric material. Polonium, U^{233}, and plutonium, on the other hand, are on an entirely different scale of toxicity than are most poisonous industrial materials. For example the maximum permissible level (MPL) of hydrogen cyanide gas in air is about 350 million times as great as the MPL for plutonium (*12*). The table shows the energy intensity and MPL of contamination for some of the insoluble alpha emitters. To keep the air count within tolerance limits, complete isolation by an impermeable barrier is necessary in handling materials such as plutonium.

One hazardous feature of plutonium is that it tends to become airborne as extremely fine particles of oxide or of some other brittle compound. It has been suggested that emitted alpha particles can dislodge fragments of plutonium and especially of plutonium oxide from the surface of the metal. Also, metallic Pu can be spread by contact of contaminated surfaces.

The low-energy X-rays of Pu can be stopped by heavy neoprene gloves. However, there are invariably considerable high-energy X-rays from radioactive impurities in the plutonium. The amount of impurities is dependent upon the history of the plutonium—e.g., pile exposure and especially efficiency of the separations process. A study of surface dosage rates of massive plutonium as a function of absorber thickness indicates that it should not be handled in the gloved hand (30–35 mils neoprene and 9–11 mils latex) for more than about 1½ hr/week (*13*). The actual time limits should be determined for the plutonium in question.

Maximum Permissible Limits of Radioisotopes in Air

Isotope	*Energy of α particle (Mev)*	*gm/curie*	*Maximum permissible limits in air*		
			NCRP (μ curies/ml)*	*Calculated*	
				(gm/m³)	*(dpm/m³)*
U-Natural			1.7×10^{-11}	5.1×10^{-5}	38
U^{238}	4.18	3.0×10^{6}	1.7×10^{-11}	5.1×10^{-5}	38
U^{235}	4.56	4.7×10^{5}	1.6×10^{-11}	7.4×10^{-6}	36
U^{233}	4.82	1.1×10^{7}	1.6×10^{-11}	1.7×10^{-9}	36
Pu^{239}	5.14	16.1	2.0×10^{-12}	3.2×10^{-11}	4.4
Po^{210}	5.3	2.2×10^{-4}	7.0×10^{-11}	1.6×10^{-14}	156
Ra^{226}	4.8	1.0	8.0×10^{-12}	8.0×10^{-12}	17.8

* National Committee on Radiation Protection.

Methods of protecting personnel. The radioactive materials that are dangerous because of penetrating gamma or neutron radiation are handled by remote control in "caves." Materials that emit alpha radiation accompanied by little or no beta or gamma radiation are normally handled in gloveboxes. The safe handling of alpha-emitters depends not only upon the enclosure design, but also upon the procedures.

Another approach, involving large equipment, is to house the operator in a pressurized suit or mobile enclosure with the equipment in a permanently contaminated inert-gas-filled room. This would permit the use of standard equipment of any size in standard arrangements. As "space-suit" techniques are further developed, this method may well be the answer to the high cost of equipment modification and enclosure associated with the glovebox approach.

Automatic operation of all equipment has been attempted in routine production facilities with some degree of success. The use of electronically operated, remote-controlled manipulators to service the equipment is still in its development stage.

Where versatility and flexibility are essential, such as in a research laboratory, the glovebox approach is the one most favored.

Pu safe-handling rules. General rules for handling plutonium in research and production operations have been prescribed by the health division of the Los Alamos Scientific Laboratory (*2*). These rules should be adhered to especially where occasional air counts exceeding the maximum permissible concentration can be expected. The following principles are emphasized because they are important to the authors' philosophy of safe glovebox-handling of plutonium for metallurgical purposes.

1. All operations must be carried out in enclosures, as nearly leakproof as possible, that provide for manipulation with arm-length gloves, aided where necessary by mechanical devices.

2. The pressure within a glovebox system should be enough less than the room pressure that, in the event of a leak, the in-leakage of air will be at least 150 ft/min.

3. Every precaution should be exercised to minimize, and if possible prevent, the formation and accumulation of fine particles or dust. Powders must be handled with particular care.

4. Exposure to oxidizing atmospheres, such as air, of plutonium or its alloys that have been prepared in inert atmospheres must be done under controlled conditions, since they may be in a pyrophoric condition.

5. Allowance must be made for radiation that penetrates gloves, thus limiting personnel exposure time.

6. Certain rules for safe practice should be established and insisted upon.

Some of these considerations may seem obvious, but how best to follow these principles is not entirely a matter of common agreement. Compromises to facilitate a job have in some cases led to extremely time-consuming, hazardous, and costly delays.

Fuel-Element-Handling Facility

Tests and operations associated with the power-breeder reactor systems involve handling intensely radioactive (α-, β-, and γ-rays) fuel elements. It is necessary to carry out these operations behind thick heavy shielding walls and at the same time maintain a very tightly enclosed facility to contain the highly toxic alpha emitters.

Electrically connected master-slave manipulators have been developed for this handling problem (Fig. 3). The high-level research cave in which these manipulators will be installed (Fig. 4) may be one of the first steps in design-

ing a facility that can be operated without personnel entering the enclosure.

Some of the requirements of the manipulators and equipment are stringent under these conditions. For instance, manipulators must be moderately easy to repair. In many cases, this is accomplished by making subassemblies into unitized packages that can be easily removed and replaced. Further developments are aimed at the manipulators' repairing each other as well as most of the equipment within the enclosure. Since there is little hope that manipulators will have the dexterity of the unhampered human hand, it will be necessary for the equipment within the enclosure to be set up, maintained, and dismantled within the limitations of the manipulators. This will probably call for extensive redesign of the equipment to be used in such facilities.

Certain items or parts of equipment and apparatus may not lend themselves readily to be repaired and maintained by manipulators. In these cases the equipment must be installed so that it can be easily removed from its working location to a low-level cell, such as cell C, where, after cleaning to reduce the gamma level, certain repairs can be made by using rubber gloves.

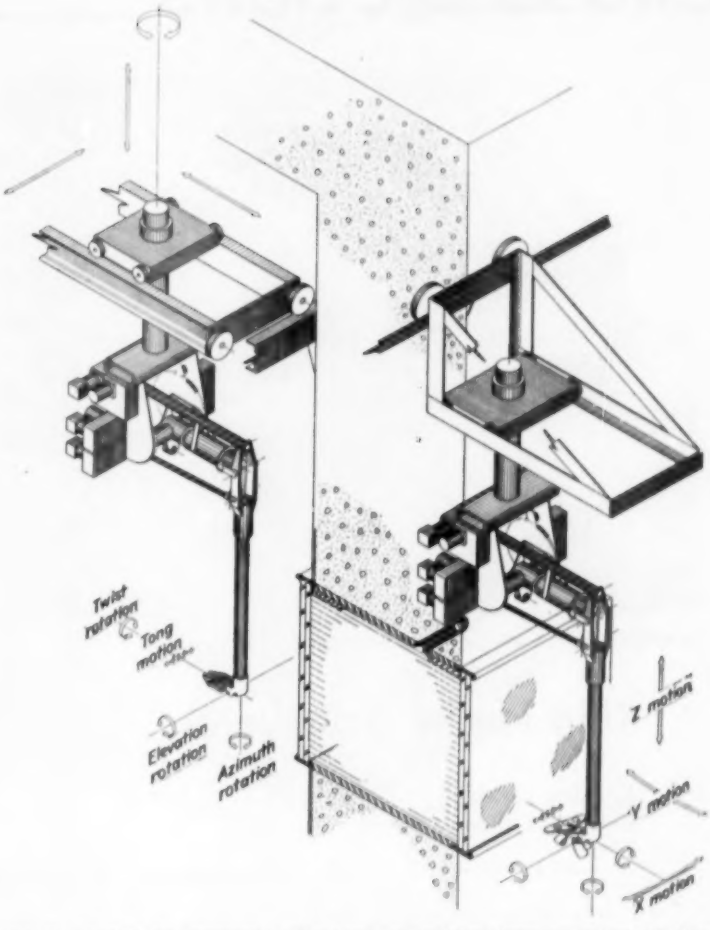


FIG. 3. Electrically connected master-slave manipulators have same basic 7 deg of motion as mechanically connected manipulators. Force-reflecting servomechanisms drive slave arm and reflect load forces back to master arm

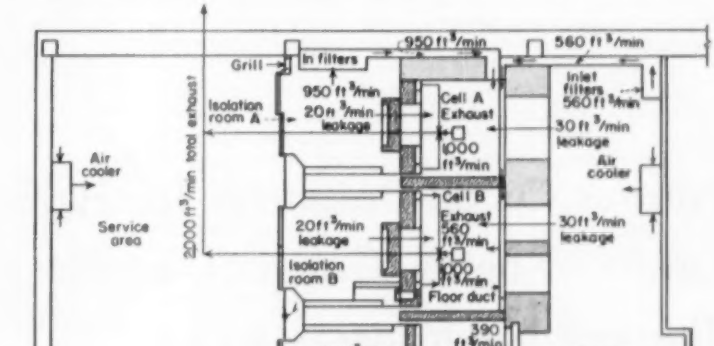
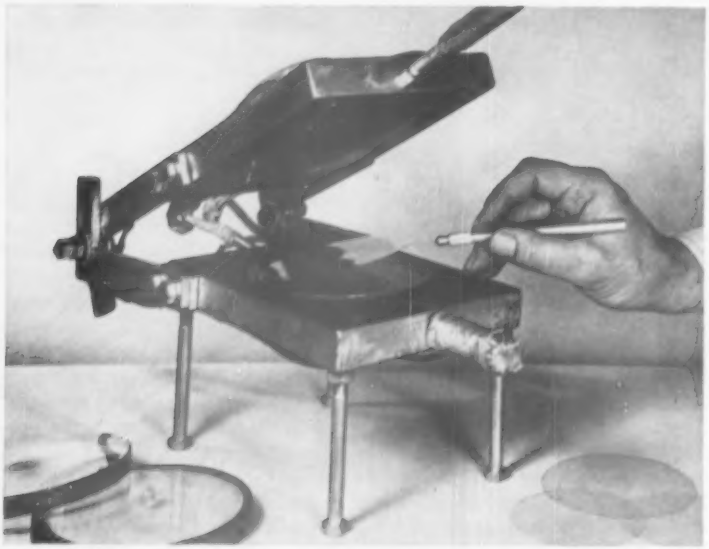


FIG. 4. Two to four master-slave manipulators serve research cave having high-level (10,000 curies, 1-Mev gamma) cells A and B and low-level cell C. Negative pressure is maintained by exhausting 1,000 ft³/min from each of cells A and B

BIBLIOGRAPHY

1. H. H. Hausner, M. C. Kells. The role of powder metallurgy in the design of nuclear power reactors (paper 55-8-24, joint session of Metals Engineering Div., Nuclear Energy Application Committee and Power Div. at the Am. Soc. for Mechanical Eng. Meeting, April 18–24, 1955)
2. E. R. Jette, A. S. Coffinberry. "Plutonium and Its Alloys," Ch. 1.15 in "The Reactor Handbook," Vol. 3, Sec. 1, AECD-3647 (1955)
3. G. R. Hall, editor. Symposium on the handling of radioactive and toxic substances, AERE C/R 958 (1952)
4. Symposium on Laboratory Design for Handling Radioactive Materials, NP-3875 (1951)
5. A. Shuck, R. Mayfield, ANL-5499
6. I. Hartman, John Nagy, M. Jacobson. Explosive characteristics of Ti, Zr, Th, U, and their hydrides, Report 4835 (U. S. Bureau of Mines, 1951)
7. B. Kopelman, V. B. Compton. Spontaneous combustion of metal powders, *Metal Progr.* **63**, 77 (1953)
8. J. M. Warde, R. M. Richardson. Waste disposal—vital to atomic power development, *Mining Eng.* **7**, 458 (1955)
9. Handbooks published by National Bureau of Standards, U. S. Department of Commerce: 42—Safe Handling of radioactive isotopes, 48—Control and removal of radioactive contamination in laboratories, 52—Maximum permissible amounts of radioisotopes in the human body and maximum permissible concentrations in air and water
10. Lecture notes; health physics training lectures, 1948–1949 (AECU-817)
11. L. S. Taylor. The basis for standards of radiation protection (Soc. for Nondestructive Testing Meeting, Oct., 1955)
12. Threshold limit value for 1955, *Archives of Ind. Health* **11**, No. 6 (1955)
13. P. R. Schiavone, W. R. Kennedy, T. N. White. Surface dose rate from massive plutonium, LA-1574 (1953)



SCINTILLATOR DISK being removed from the oven press

Thin Plastic Scintillators

By CHRIS LAGISS
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Livermore Site
Livermore, California

Plastic scintillators—usually 0.5–1 in. disks, 1–10 mil thick—have been useful in our laboratories for counting alphas and protons. Because of the thinness, gammas and betas are discriminated against.

The plastic disks are made by pressing plastic beads in the oven illustrated. The pressing surfaces are glass plates (4-in. diameter, 0.25–0.5 in. thick) in this case. However, any similar highly polished surface will do, e.g., chromium or brass. The bead-shaped pellet consistently produces the best disks.

The procedure is as follows:

1. Preheat the glass or other plates in an oven at about 160° C. A higher temperature melts the plastic and creates bubbles. A lower temperature prolongs the process.

2. While the plates are heating, make the plastic pellet and polish it. Rough surfaces on the pellet retain impurities that discolor the center of the disk.

3. Take the plates from the oven and apply a thin coat of a plastic-release agent. Wipe the plates clean, leaving a thin coat of the agent on the disk. The release agents used here are soluble oils (with no water) or various silicone greases; a water suspension of almost any silicone oil is satisfactory. If too much agent is used, the disks will not be of uniform thickness.

4. Place the plastic pellet in the center of the plates and place the spacer around the edge of the plate. The spacer may be a brass ring or several shims around the inner edges between the two plates. Spacer thickness depends on the disk thickness desired as well as compensation for the coefficient of expansion difference of the spacer and plastic.

5. Put plates and ring back in the oven. Pressure may be applied with a lead brick or other weight.

6. Allow the plates to cool slowly when taken from the oven. Rapid cooling sometimes causes fractures in the disk.

* * *

This work was done under the auspices of the U. S. Atomic Energy Commission.

Nitrous Oxide Dosimeter for High Levels of Betas, Gammas, and Thermal Neutrons

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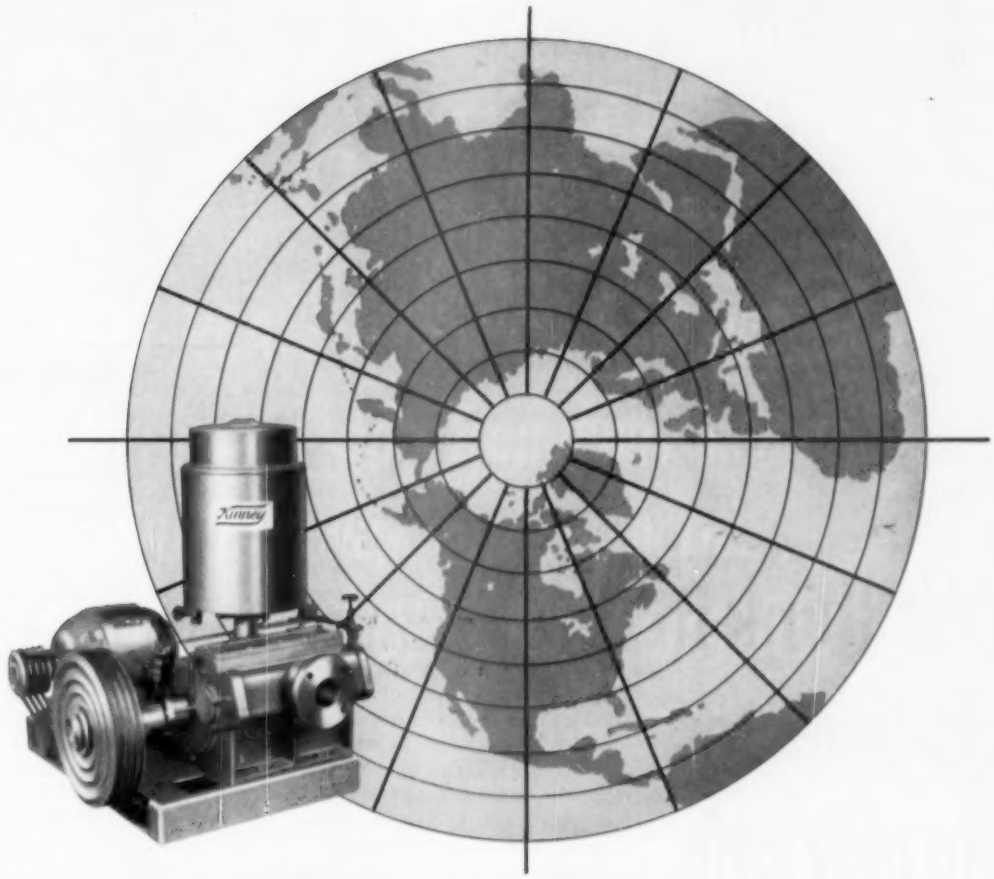
In the study of the radiation chemistry of the nitrogen-oxygen system (*1*), a simple high-level dosimeter for the measurement of beta and gamma radiation and also for thermal neutrons was found in the use of nitrous oxide, which decomposes proportionately to the dosage of the ionizing radiation. The equipment for dosimeter filling and dosimeter analysis is simple and not expensive and includes a small vacuum system and possibly a colorimeter. The physical properties of the nitrous oxide, e.g., ease of purification, comparatively small thermal-neutron cross section, indefinite shelf life, and usefulness in the temperature range of −80° C to 200° C, add to its attractiveness. In addition, the products of decomposition, by beta and gamma radiation and by thermal neutrons (U^{235})—nitrogen, oxygen and nitrogen dioxide—are readily measured by vacuum techniques. If desired, the nitrogen dioxide (when in sufficient quantity) may be measured colorimetrically without opening the irradiated vessel. These products of decomposition do not interact and may therefore be measured at any time after irradiation.

Studies on the calibration of the



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nitrous oxide dosimeter have been made using the Brookhaven National Laboratory reactor, at 10^6–10^{10} r, and compared directly with the Brookhaven cobalt-60 sources, 5×10^4 to 3×10^7 r.

Experimental

For pile irradiation, tank nitrous oxide (Matheson Co.) was purified and sealed in 20-cm³ quartz vessels (Amersil Co.) to a pressure of 650 mm. Where higher doses were desired, 5 mg of $U^{238}O_2$ was inserted as a powder prior to the addition of the gas. After sealing, the samples were irradiated at predetermined time intervals in the BNL reactor—operating at 24 Mw, 2.7×10^{12} neutrons/cm²/sec, and 70° C.

For irradiation in the cobalt-60 sources, nitrous oxide was sealed in 87-cm³ Pyrex vessels (Wilt Glassblowing, Inc.) to a pressure of 500 mm at 0° C.* These were irradiated in four different cobalt-60 sources, previously calibrated by BNL personnel with a ferrous sulphate dosimeter and ion chambers.

After irradiation, in either case, the seals were broken in vacuum. After condensing the nitrous oxide remaining and the nitrogen dioxide formed in a liquid nitrogen bath, the nitrogen and oxygen were measured with an alphatron vacuum gage (National Research Corp.). The oxygen-to-nitrogen ratio was measured by burning the oxygen with hydrogen, and determined only when desired. Nitrous oxide remaining was measured at dry-ice-bath temperature, where nitrogen dioxide has almost no vapor pressure (B.P. +20° C). Complete analysis takes about 30 min. In actual practice, only the sum of the nitrogen and oxygen need be measured. At high dosages, the nitrogen dioxide may be measured, if desired. All pressure measurements were made with an alphatron gage.†

Results

The nitrogen, oxygen, and nitrogen dioxide production with varying doses is shown in Fig. 1. At low doses, the nitrogen dioxide is difficult to measure and therefore omitted here. The sum of the nitrogen and oxygen formed is shown in the curve, as would be measured in normal practice. At 3×10^7 to 3×10^9 r, nitrogen dioxide is readily perceptible and can be measured colorimetrically, with the vessel unopened. A double check may be made by measuring the nitrogen and oxygen.

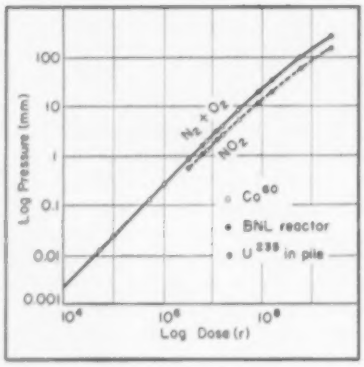

FIG. 1. Calibration of N_2O dosimeter

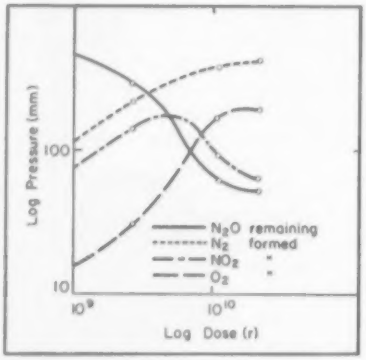

FIG. 2. Equilibrium of radiation-decomposed N_2O

Above 3×10^9 r, the decomposition of nitrous oxide approaches equilibrium, as shown in Fig. 2. A well defined equilibrium state was obtainable in all the nitrogen-oxygen mixtures. At the equilibrium state, only nitrogen, oxygen, nitrogen dioxide, and nitrous oxide were present. In this region, the dosimeter is no longer accurate (see Fig. 2). Under controlled conditions, it may, however, be useful.

Discussion

The kinetics of the nitrous oxide decomposition by ionizing radiation is fairly simple in the initial stages, but becomes more complex at doses higher than 10^9 r and is not detailed here. However, the complete study of the oxides of nitrogen has been accomplished and will be published soon. From this study, we learned that nitrous oxide is not attacked by nitrogen or oxygen atoms, or any ion reac-

* The use of 500 mm of nitrous oxide at 0° C, we feel is comparable to one atmosphere of air for measuring the roentgen. For more accurate determinations, a slight correction may have to be applied.

† For the absolute pressure of NO_2, the NO_2 pressure as measured by the gage should be reduced by one-third, and for the N_2O_4 by two-thirds. The NO_2-N_2O_4 equilibrium does not effect the gage measurements.

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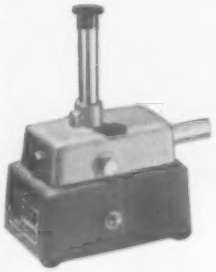

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tions, and thus seems to be an ideal dosimeter material.

The decomposition of nitrous oxide is an exactly linear function of dosage to 10^7 r and practically linear to 10^8 r. In this region, it is also intensity and temperature independent, according to our measurements.

The main reactions in the decomposition of nitrous oxide by ionizing radiation are

$$N_2O \longrightarrow N_2O^* \longrightarrow N_2 + O \quad \sim 80\%$$
$$N_2O \longrightarrow N_2O^+ + \epsilon^- \longrightarrow N + NO \quad \sim 20\%$$
$$2\,NO + O_2 = 2\,NO_2$$
$$NO_2 + N \rightarrow 2\,NO$$
$$\rightarrow N_2O + O$$
$$\rightarrow N_2 + O_2$$
$$N_2O^+ + NO = N_2O + NO^+$$
$$NO^+ + \epsilon^- = N + O \text{ or } NO + h\nu$$

With the decomposition of nitrous oxide by ionizing radiation being temperature independent, the lower temperature of usefulness is limited by the vapor pressure of the nitrous oxide, which at −81° C, is one atmosphere. The higher temperature is limited by the thermal decomposition of nitrous oxide. For example, at 200° C nitrous oxide is indefinitely stable to thermal decomposition. For short-time irradiations, temperatures above 200° C could be used. The thermal decomposition of nitrous oxide is a first-order reaction. The decay constant is given by the formula

$$K = 4.2 \times 10^9\, e^{-53{,}000/RT}\ \text{sec}^{-1}$$

Some wall catalysis may add to this rate of decomposition.

It should be indicated that pile irradiation has been carried out using nitrous oxide with and without uranium-235 present, from one atmosphere to almost its critical pressure (i.e., liquid nitrous oxide). The results showed that the decomposition mechanism was unchanged and independent of whether cobalt-60 sources, pile irradiation, or fission products were used (an intensity range of over four decades), or whether irradiation was conducted at room temperature or 150° C, since the ratio of the decomposition products remained the same within the limits of our accuracy. The ratio was

$$N_2 : O_2 : NO_2 = 1 : 0.14 : 0.48$$

This indicated that nitrous oxide decomposes independently of temperature, pressure, intensity, and of the decomposition products present, since the dual decomposition ($N_2 + O$ and $N +$

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NO) is not affected by these parameters. Only after a reasonable amount of nitrogen dioxide is formed (see Fig. 2), does the reaction become more complex.

Duplications of experiments have run within 1% of each other. Verification of the calibration using the cobalt-60 sources had been better than anticipated within our limits of error.

From our experimental results and from E. E. Wourtzel's work reported in S. C. Lind's classical book (*3*), 4.2 ± 0.1 molecules of nitrous oxide are decomposed per ion pair formed, a G value of 12.

The measurement of thermal neutrons was accomplished by adding 5 mg of uranium-235 oxide to the reaction vessel. Under these conditions, the decomposition due to the neutron-induced fission was about sixty times greater than that due to the beta and gamma radiation in the pile. The uranium-235 can be readily substituted with other materials, such as boron, lithium, or natural uranium. It was noted in these experiments that the fission products tend to distribute themselves uniformly over the vessel. The results between identical samples were readily reproducible and not a function of the position of the uranium powder as might have been anticipated.

Conclusions

In the range 5×10^4 to almost 10^{10} roentgen, this dosimeter can be readily used for the measuring dosage in food sterilization, enzyme deactivation, pasteurization, and for determining dosage contours in nuclear reactors. Neutron fluxes can be measured by adding small amounts of uranium-235 in the capsule. Dosages at elevated temperatures may also be readily determined (to over 200°). We also think this dosimeter to be very valuable in comparing world-wide dosimetry measurements.

* * *

We would like to thank Dr. M. Fox and Messrs. R. Powell, J. Floyd, F. Reeve and H. Donahue of the Reactor Dept. for their advice and cooperation in the pile experiments, and Messrs. O. Kuhl and R. Chapman of the Brookhaven National Laboratory Nuclear Engineering Dept. for conducting the irradiations with the cobalt-60 sources. This work was supported by the U. S. Atomic Energy Commission under contract At (30-3)-52.

BIBLIOGRAPHY

1. P. Harteck, S. Dondes, to be published
2. P. Harteck, S. Dondes, *J. Chem. Phys.* **22,** 953 (1954)
3. S. C. Lind, "The Chemical Effects of Alpha Particles and Electrons" (Reinhold Publishing Corp., New York, 1928)

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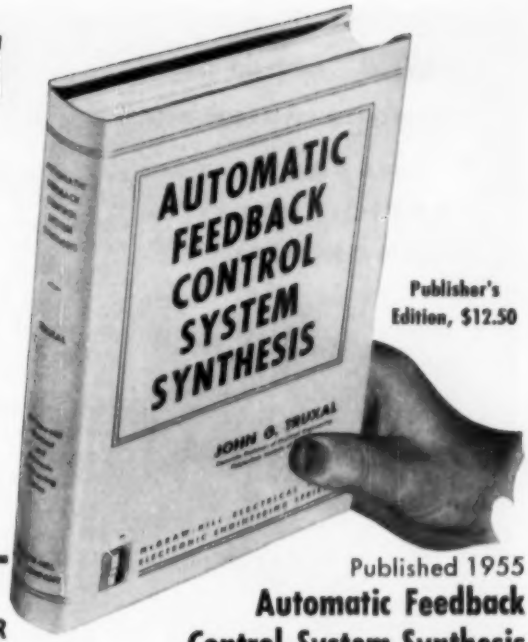

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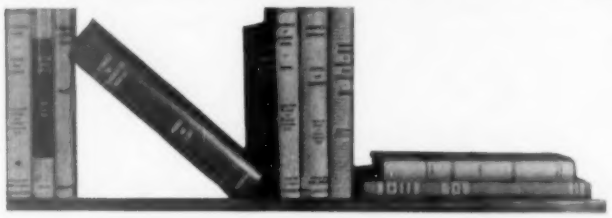

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Battery life of seven mercury cells is 440 hr with an output voltage drop of 0.55%. The design objective was that the circuit must accept this voltage decrease over its battery life and offer interchangeability of transistors with only simple adjustments—a rather exacting requirement because of the variation of characteristics among transistors available.

Considerable output power was realized with the circuit of Fig. 3. The two transistors in alternate-firing arrangement offer a combined collector dissipation of 60 mw. The balanced output of T_2 (United Transformer Co. "ouncer" type 0-3) presents a signal suitable for voltage doubling, which helps in two ways: (1) the possibility of transformer breakdown is lessened with the voltage on the secondary of T_2 nearly halved; (2) more of the rectified current is available at the output since each selenium rectifier is subjected to only 450 volts during most of the cycle, producing a back current of less than 0.4 μa. Because of the variation of characteristics among transistors, R_1 and R_2 must be adjusted for each different pair, R_1 changing peak current and pulse width, R_2 determining repetition rate.

Circuit Performance

Tests were made with the oscillator-rectifier-regulator system using parameters important in portable instrument use, i.e., change of high-voltage output under load with varying battery voltage and ambient temperature (Fig. 2). Also the total output current (including voltage-regulator tube) is plotted against battery voltage in Fig. 3. Since the minimum high-voltage output current capable of operating a voltage regulator and photomultiplier (B in Fig. 3) was reached within a few hours of the end of useful battery life,

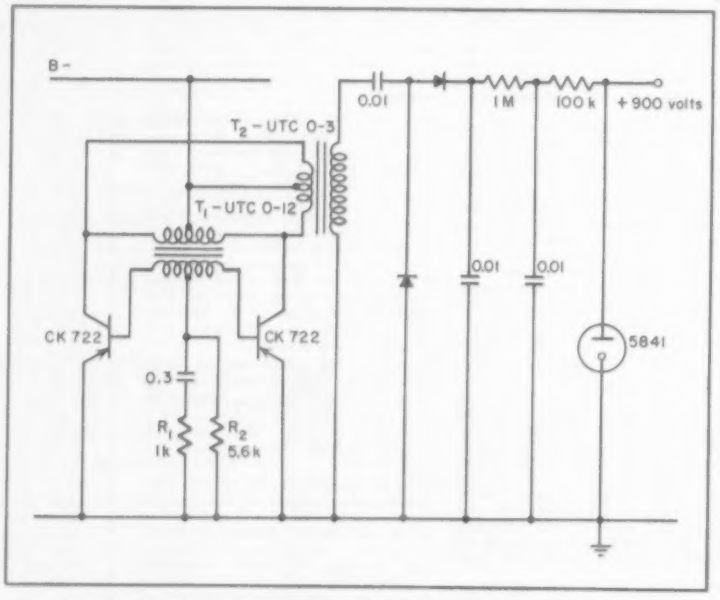
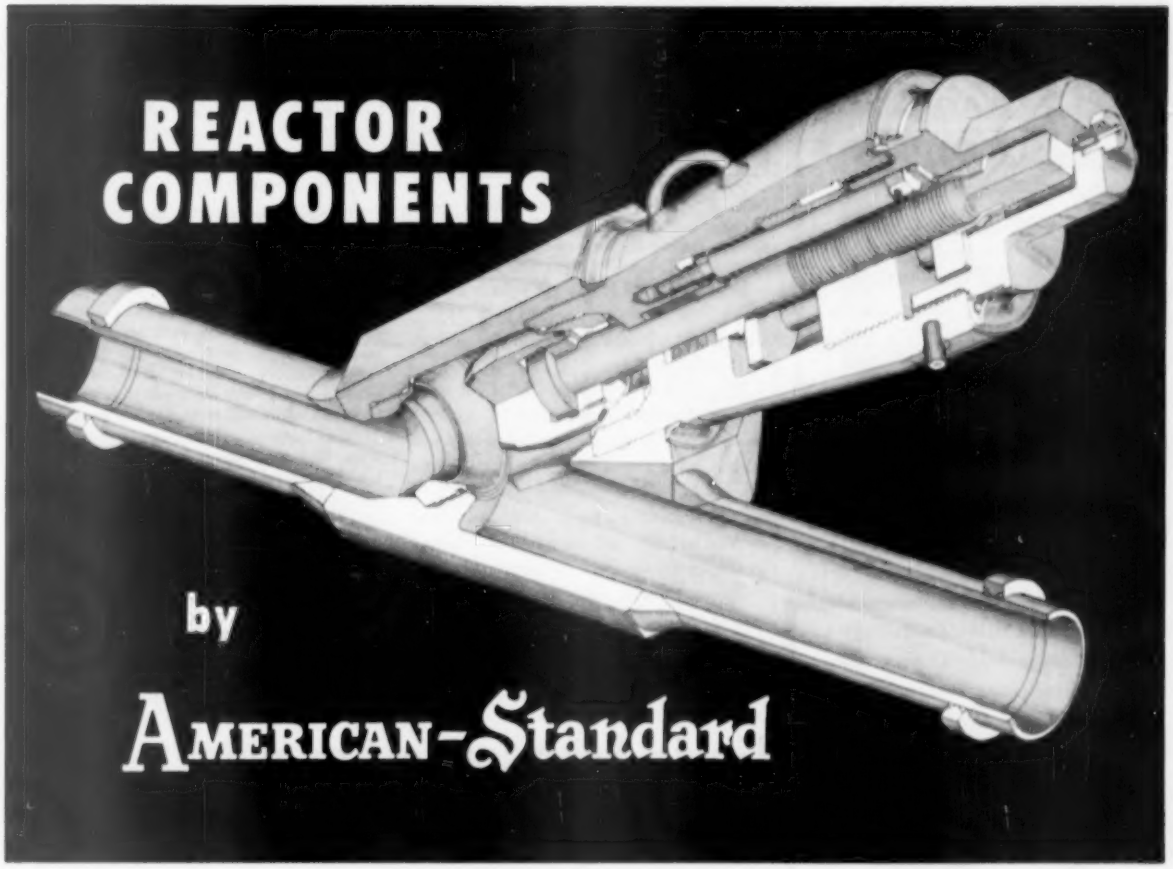


FIG. 1. Alternate-firing oscillator high-voltage supply is suitable for portable Geiger and scintillation counters



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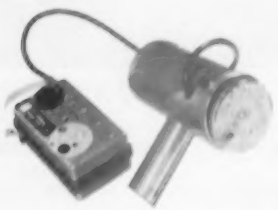

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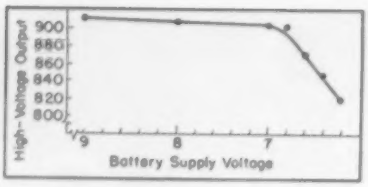


FIG. 2. Change in high voltage with varying battery voltage. Drop-off at 6.9 volts is caused by lack of sufficient voltage to fire regulator tube. Output-voltage regulation from 9 to 7 input volts is 0.55%

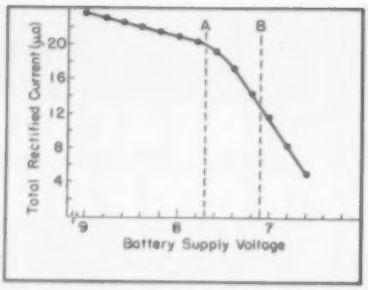


FIG. 3. Change of load and regulator current with battery voltage. "A" corresponds to 1.1-volt/cell end point with seven mercury cells in series, at which average cell is nearly discharged. This occurred after 440 hr continuous operation. "B" is battery voltage producing minimum high-voltage output current capable of operating voltage regulator and photomultiplier

the circuit utilizes nearly all the energy of the battery.

The circuit was operated in a controlled chamber at +125° F to −25° F. No change in output voltage was observed until the temperature fell below zero. At −25° F, a drop of 1.4% in output voltage was observed that proved to have been caused by a change in the corona-regulator characteristic.

No transistor damage by moisture was apparent after circuit operation at 9% relative humidity for 475 hr. The test was discontinued because of battery failure.

The circuit weighs 4.5 oz without mounting plates and occupies less than 5 in³.

Liquid-Scintillation Counting for Assay of Tritium in Urine

By GEORGE T. OKITA, JAMES SPRATT and GEORGE V. LEROY
Argonne Cancer Research Hospital
The University of Chicago
Chicago, Illinois

Increasing use of tritium gas and tritium water in chemical syntheses and other processes has resulted in the need for a simple, rapid, and sensitive method for monitoring personnel exposed to possible contamination with isotopic tritium. Because of the prompt equilibration of tritium gas and tritium water with body water, the routine determination of the tritium content of urine is a satisfactory procedure for monitoring personnel working with this nuclide. The methods commonly in use for the radioassay of urine containing tritium (as THO) require a vacuum combustion line. The tritiated gas obtained must be transferred into either an ionization chamber (*1–6*), an internal Geiger counter (*7–10*), or a proportional gas-phase counter (*11–13*). Hayes and Gould (*14*), and Farmer and Berstein (*15*) have described methods for the assay of tritium-labeled water and organic compounds using a fast-coincidence liquid scintillation counter.

This article describes a simple, rapid, and sensitive liquid-scintillation method for monitoring the urine of workers exposed to tritium.

Sample Preparation

Thirty ml of urine are mixed thoroughly with approximately 1 gm of activated charcoal (N.F. IX, Mallinckrodt) and then filtered. The colorless filtrate is used for radioassay without further treatment. Three samples are prepared:

1. Test specimen. Pipette 2.0 ml of decolorized urine, 0.1 ml distilled water and 20.0 ml absolute ethanol (U.S.I.-U.S.P.) into an 85-ml (50 × 60 mm) weighing bottle. After initial mixing, add 28.0 ml reagent-grade toluene and 100 mg scintillation-grade *p*-diphenyloxazole. Mix thoroughly to obtain complete miscibility.

2. Background blank. Sample preparation is the same as for the test specimen except that 2.0 ml of distilled water are used in place of 2.0 ml of decolorized urine to give a total of 2.1 ml water.

3. Internal standard. Sample prep-

aration is also similar to the test specimen except that 0.1 ml standard THO solution (assayed by the method of Wilzbach *et al.* (*5*) using the vibrating-reed electrometer) is used in place of 0.1 ml distilled water.

The internal standard sample is needed to determine the counting efficiency, E_s, of the solvent system and counter. Since the amount of quenching substance in each decolorized urine sample varies from one specimen to another, internal standards should be run with each test specimen if accurate assay is desired. However, for a large-scale monitoring program a more practical approach would be to take the average of three different E_s determinations and use this figure for all subsequent urine assays made during the same day. By setting an arbitrary upper limit for tritium activity of 10 or 20 μc per liter of urine [maximum permissible concentration of tritium in body water is 200 μc per liter (*16*)!; all samples assaying close to this upper limit can be reassayed more accurately using individual internal standards.

Assay of Samples

Radioassay is performed in a fast-coincidence liquid scintillation counter.* The samples are allowed to equilibrate to a temperature of 6° C in the refrigerator unit that houses the photomultiplier tubes. Samples are counted long enough to give a standard error of less than ±5%. The over-all counting efficiency for tritium water samples at this temperature is approximately 3% using our present counter. However, efficiency varies from counter to counter depending upon the scintillator system used, the phototubes, and the type of circuitry.

Radioactivity of the urine sample,

* Tri-Carb Counter, Model 314, Packard Instrument Co., La Grange, Ill.

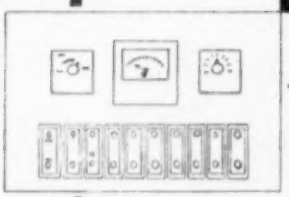
TABLE 1—Quenching Effect of Various Samples

*Type of urine sample**	*Quenching*† (%)
Decolorized urine filtrate	None–12
Nonprocessed urine (medium color)	56–87
Nonprocessed urine (dark color)	78–100

* Six different urine samples used for each category.

† Comparison with the external standard.

Jordan Remote Area Monitoring Systems



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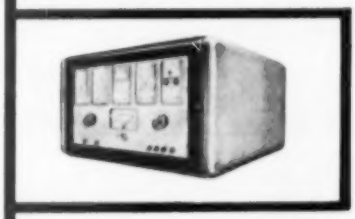

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D_u, can be determined from the following formulas where C_u equals counts per minute (cpm) of urine sample, C_i equals cpm of the internal standard, C_b equals cpm of the background blank, and dpm equals disintegrations per minute.

$$E_s = \text{efficiency of solvent system and counter} = \frac{(C_i - C_b) - (C_u - C_b)}{\text{dpm of 0.1-ml stand. tritium } H_2O}$$

$$D_u = \text{dpm of 2 ml of urine} = \frac{C_u - C_b}{E_s}$$

The total radioactivity is then expressed as

$$\mu c \text{ per liter of urine} = \frac{D_u \times 500}{2.22 \times 10^6 \text{ dpm}}$$

Factors Affecting Results

A number of scintillator-solvent systems were studied with respect to their efficiency for counting tritiated water. Some of the more successful systems were phenyl cellosolve-water, ethylene glycol-water, dioxane-water, and benzyl alcohol-methanol-water. The one described in the previous section, which is a modification of the system suggested by Hayes and Gould, was the most suitable.

It was assumed at the outset that the counting efficiency would be influenced by the color of the urine, by its salt content, and by other organic substances with the capacity to quench the tritium scintillation. Coloring substances and a number of quenching substances are readily removed from urine by adsorption on activated charcoal. A clear filtrate results that displays little evidence of a quenching action.

The effect of color and other quenching agents was examined by comparing the counting rate of various urine samples against an external standard (distilled water used in place of urine filtrate) containing the same amount of radioactivity. The composite results are shown in Table 1. The quenching effect of decolorized urine ranged from 0 to 12%; in the case of unprocessed urine, the quenching was 56–100%. At the outset of the study it was assumed that the electrolytes of urine might have a quenching effect, and samples were passed through ion-exchange resin columns (amberlite MB-1) to remove anions and cations. The gain in efficiency was too small to make this additional step worthwhile.

The reliability of the urine assay was determined by adding varying amounts

TABLE 2—Limit of Sensitivity of Assay Method

Urine sample (2 ml)	*Specific activity of urine (μc/liter)*	*Obs'd. net cpm (2 ml urine)*
1	0.50	68
2	0.20	27
3	0.10	13
4	0.08	trace*
5	0.05	NSC†
6	0.01	NSC

* Net cpm between one to two S.D. of background counts.

† No significant counts—net cpm less than one S.D. of background counts, i.e., less than 6 cpm.

of the standard THO solution to non-processed urine. The amount added was never more than 5 ml per 100 ml of urine. The urine samples were than decolorized, and counting was done in the manner described previously. The recovery for 10 samples treated in duplicate was 96.7 ± 7.5% standard error of the mean.

The limit of sensitivity was determined by preparing a series of urine samples containing decreasing amounts of the standard solution of THO. These were then decolorized and counted in the usual manner. The results are shown in Table 2. For statistical purposes, the net counts per minute of a sample was considered significant when it was greater than two times the standard deviation of the background rate. The standard deviation was determined by applying the formula, S.D. = $\sqrt{\Sigma d^2/(N-1)}$ (where d is the deviation from the mean), to a series of eight separate background samples all counted for a minimum of 30 min. When the net counts per minute of a sample were between one and two standard deviations, the value is reported as "trace" activity. Samples with net counts less than one standard deviation of background are reported as no significant counts (NSC).

Table 2 shows that urine containing as little THO as 0.08 μc per liter can be detected by this method. This lower limit of sensitivity corresponds to a total body burden of tritium of the order of 3–4 μc, which is well below the maximum permissible amount of 10^4 μc (*16*).

* * *

We are indebted to Shirley Woolfolk and Florence Richardson for technical assistance.

BIBLIOGRAPHY

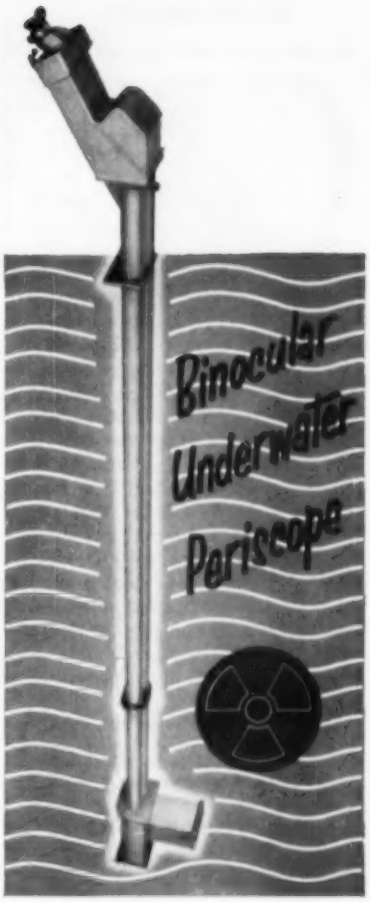
1. F. C. Henriques, Jr., C. Marguetti, *Ind. Eng' Chem., Anal. Ed.* **18,** 420 (1946)
2. P. Verzaux, *J. Phys. Radium* **13,** 94 (1952)
3. E. A. Pinson, *Physiol. Rev.* **32,** 123 (1952)
4. M. W. Biggs, D. Kritchevsky, M. R. Kirk, *Anal. Chem.* **24,** 223 (1952)
5. K. E. Wilzbach, L. Kaplan, W. G. Brown, *Science* **118,** 522 (1953)
6. R. C. Thompson, J. E. Ballou, *J. Biol. Chem.* **206,** 101 (1954)
7. M. L. Eidenoff, *J. Am. Chem. Soc.* **69,** 2504 (1947)
8. L. Melander, *Acta Chem. Scand.* **2,** 440 (1948)
9. R. F. Glascock, NUCLEONICS **9,** No. 5, 28 (1951)
10. J. Wing, W. H. Johnston, *Science* **121,** 674 (1955)
11. W. Bernstein, R. Ballentine, *Rev. Sci. Instr.* **21,** 158 (1950)
12. C. V. Robinson, *Rev. Sci. Instr.* **22,** 353 (1951)
13. P. R. Payne, I. G. Campbell, D. F. White, *J. Biochem.* **60,** 500 (1952)
14. F. N. Hayes, R. G. Gould, *Science* **117,** 480 (1953)
15. E. C. Farmer, I. A. Berstein, *Science* **117,** 279 (1953)
16. National Bureau of Standards Handbook 52 (Government Printing Office, Washington 25, D. C., 1953)

Remote Tongs Adapted for the Small Radioisotope Laboratory

By L. E. PREUSS
Edsel B. Ford Institute for Medical Research Detroit, Michigan

The need for remote custom tongs of varied design is always urgent in the small radioisotope laboratory, where they are used for handling various odd-shaped "hot" containers. This type of instrumentation is frequently lacking because of its costly nature. Usually one or possibly two devices are required to serve for all the specialized handling problems, oftentimes with inefficient and troublesome results.

The practice here has been to adapt the ordinary tongs and forceps found in the chemical laboratory. Lack of rigidity and precision construction make these mutations less than useful. The purpose of this note is to describe a quick, inexpensive solution to this and to show how the minimum labora-



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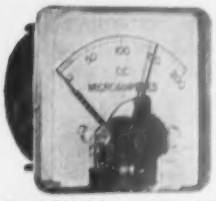

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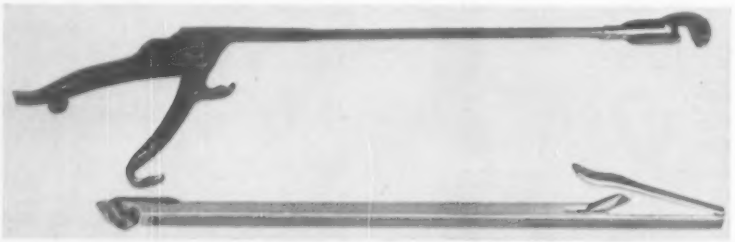
tory may be provided with several tongs, each for a specific use.

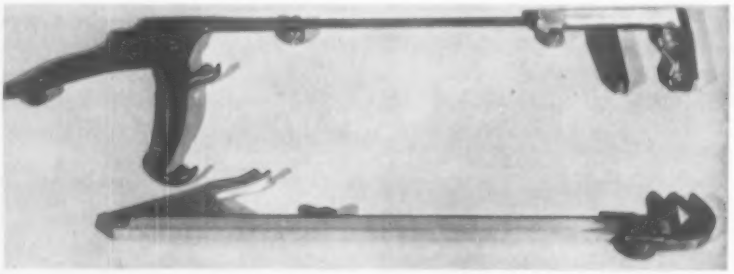
The most frequent manipulation for remote work in the small operation is for an extended, grasping, or holding mechanism to carry or move volumetric flasks, pipettes, test tubes, small cylindrical shields, etc., for sample transfers behind the conventional lead wall shield. This largely involves loads below 1 kg. The devices described are for this weight range.

* * *

Acknowledgment is made to Mr. R. Leek, Instrument Shop, for extraordinary skill in the machine work done.



TWO TYPES of commercial extension cutters for garden use (R. H. Bouligny, Inc., Charlotte, N. C. and Wiss and Co., Inc., Newark, N. J.) consist essentially of spring-actuated handle at one end and a shaft within tubular extension that drives cutting head at opposite end against metal cutting block. Basic mechanism is almost exactly that required for most remote handling, and cutters are sturdy enough for 90% of remote manipulations involving loads less than 1 kg. Total cost of alteration, exclusive of labor, is well below five dollars, and resulting tongs are sturdier and more precisely constructed than modified laboratory tongs and forceps



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LARGER TONGS use combination of Lucite and aluminum for jaws and were intended for gripping beakers and other glassware under 4-in. diameter. Slotted aluminum bar is mounted on extension tube; jaw face has vee-cut Lucite liner to give 3-point contact. Inner straight aluminum jaw is lined with neoprene. Entire head can be rotated about axis of extension tube when knurled screw is loosened. Automatic lock can be provided by grooving edges of inner jaw that bear on slotted way; base of jaw is then set into metal slot when grip is taken on object

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Recent Developments in Glass Dosimetry

By NORBERT J. KREIDL and GERALD E. BLAIR

Bausch & Lomb Optical Company
Rochester, New York

A system of high-level dosimetry that utilizes the absorption changes in glasses measured on a suitable spectrophotometer was reported recently.*

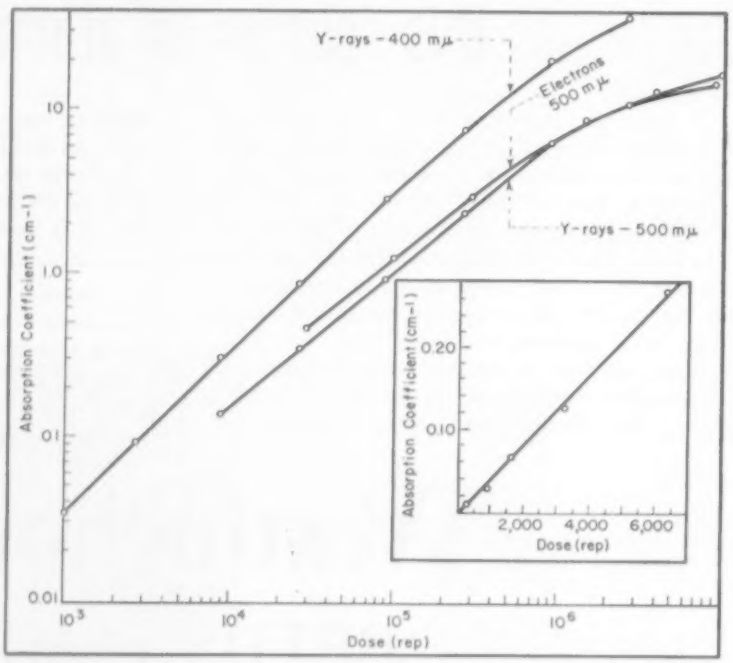
A newly developed glass has essentially stable radiation-induced absorption bands as indicated in the table. The absorption change is used to indicate dosage from a few hundred to 10^7 rep. This glass, Melt F-0621, has the following composition in mol %: SiO_2—62.5, Na_2O—10.6, B_2O_3—20.8, Al_2O_3—6.0, Co_3O_4—0.1.

The high-dose curves were obtained with 15 × 6 × 1.5 mm samples to allow readings to be taken in the Bausch & Lomb Spectronic 20 Color-

* Norbert J. Kreidl and Gerald E. Blair, NUCLEONICS **14**, No. 1, 56 (1956).

Fading of Irradiated Glass after Storage in Dark at Room Temperature

		Fading (%) normalized at 1 hr after various irradiation doses			
Measuring wavelength	*Storage time*	10^4	10^5	10^6	10^7
350	1 day	No fading	No fading	No fading	Too dense
	1 week	No fading	No fading	7	to read
	2 months	3	5	9	
400	1 day	No fading	No fading	4	Too dense
	1 week	No fading	2	10	to read
	2 months	No fading	4	12	
500	1 day	No fading	2	7	8
	1 week	No fading	6	18	14
	2 months	No fading	12	23	23



CHANGE IN ABSORPTION of F-0621 cobalt glass with Co^{60} gamma and 2-Mev electron irradiation for megaroentgen dosimetry. The insert shows change in absorption of F-0621 cobalt glass with Co^{60} irradiation for miniature dosimetry

imeter with Adaptor.* The radiation was from a 200-curie cobalt-60 gamma source at Baus·h & Lomb and a 2-Mev Van de Graaff electron accelerator at High Voltage Engineering Corp. (Cambridge, Mass.). The data of the insert were obtained with samples of 25-mm diameter and 6-mm thickness. The 200-curie cobalt-60 gamma source was used for irradiation.

As can be seen from the illustration, this glass shows good linearity of response up to 10^6 rep with somewhat less sensitive response in the 10^6–10^7 rep range. Reproducibility studies indicate good control, similar to that reported for the F-0450 glass earlier.

An instrumentation program is underway to read dosage on a 1-mm-diameter, 6-mm-long needle of this glass in the 100–5,000 rep range (insert) for the miniature-dosimeter application originally proposed by Schulman and Etzel.†

A detailed report on this development will be presented in a future publication.

---

† J. Schulman, H. Etzel, *Science* **118,** 184 (1954).

TECHNICAL BRIEF

New soldering technique. A method for soldering metals, soft glass, Pyrex, and ceramics in any combination was developed by Joseph C. McGuire, Los Alamos Scientific Laboratory. It requires, in addition to the usual soldering materials, a hand grinder with abrasive wheel.

The abrasive wheel (preferably preheated) is brought to bear on a soft solder, e.g., Wood's metal or 60-40 lead-tin, until it melts and flows onto the wheel. The solder-loaded wheel is then applied to the surfaces to be soldered until a slight amount of abrasion has taken place. The friction melts the solder, which flows onto the surface.

After this tinning operation, soldering is done in the usual manner with standard 50-50 lead-tin solder. No soldering flux, surface cleaning, or pretreatment is used.

For soft glass, Pyrex, and ceramics, the best tinning is done with a mixture of Wood's metal and 50-50 indium-tin. When soldering glass to glass or ceramic to ceramic, flame or furnace heating are needed to get enough heat to the surfaces.

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NUCLEONICS
330 W. 42nd St.
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Automatic Neutron-Flux Scanner

By R. T. FROST and E. B. FEHR
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Schenectady, New York

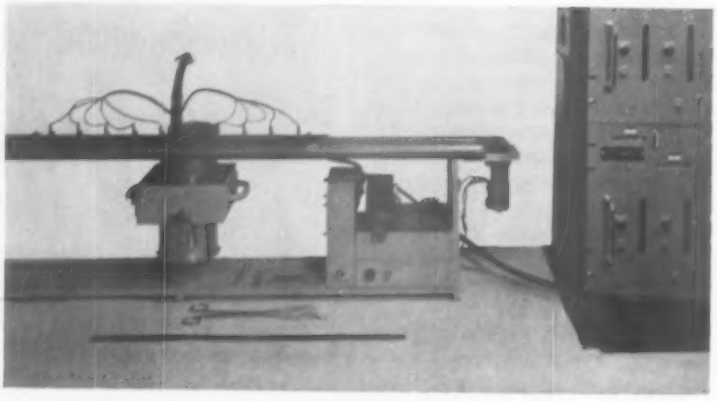


FIG. 1. Automatic neutron-flux scanner with multi-channel scalers and adjustable scale factor. Sample is moved back and forth across the detector by a self-braking motor adjusted to equal forward and reverse speeds. Motor stops each time a preset position $x = x_j$ is reached, and the appropriate scaling channel is opened for a predetermined timing interval. Motor reversal occurs each time end of sample reaches detector slit

The removal of power in the form of heat is one of the central problems of power-reactor design. Thus, the relative amounts of heat generated in different regions of a reactor core form an appropriate starting point for the consideration of the engineering feasibility of a particular critical experiment.

Other reasons for studying the spatial variation of power and flux are: (a) power gradients across a fuel element contribute to thermal stresses that might warp it; (b) gradients in flux distribution influence the reactivity value of reactor materials; (c) fission-product poison production is proportional to the specific power level.

Plots of the experimentally determined distribution of subcadmium and epicadmium fission rates afford a means of comparison with crude two-group calculations. If, in addition, one has foils of materials having an outstanding resonance at some single energy, it is possible to use self-absorption techniques to measure the distribution of the component of the neutron flux having this particular energy.

Various methods have been described for carrying out flux distribution measurements, such as moving a small neutron or fission counter slowly through the reactor and observing the variation in counting rate as a function of position (*1*).

In experiments carried out in high neutron fluxes, the induced activity in a long sample of uranium can be measured as a function of position along the sample by scanning it with a counting-rate meter.

However, with low neutron fluxes, the relatively low counting rate dictates a slow scanning speed so that statistical fluctuations in the recorded curve are not excessive. On the other hand, the low counting rate also requires that the counting be done soon after the sample irradiation, at which time the induced activity is still decaying rapidly. This imposes a requirement of a fast scanning speed so that the activity does not decay appreciably during the time required to scan. Of course, it is possible to correct the data obtained with a slow scanning speed for the effects of the decay. Since the decay of uranium depends on the duration of irradiation, this must be timed accurately.

The scanning device described here (Fig. 1) corrects automatically for any smooth time decay of radioactivity during scanning without recourse to an empirical decay curve. Exact knowledge of the duration of pile irradiation or its end point is not required.

Principle of Operation

When a long, thin sample is irradiated in an inhomogeneous neutron flux, the induced radioactivity A, after irradiation has ceased, is given as a function of position x along its length and the time t by

$$A(x,t) = f(x) \cdot g(t)$$

where f gives the variation with position and g represents the time decay of the radioactivity.

If n is the total number of points along a strip whose relative activities are to be compared, and the activity is measured at $x = x_j$ at time t_j and again at time t_{2n-j+1}, the counts recorded will be proportional to

$$f(x_j) \cdot [g(t_j) + g(t_{2n-j+1})]$$

Comparing this to the counts recorded at $x = x_1$, for example, the ratio is

$$\frac{f(x_j)}{f(x_1)} \cdot \frac{g(t_j) + g(t_{2n-j+1})}{g(t_1) + g(t_{2n})} = \frac{f(x_j)}{f(x_1)} R$$

If the intervals $t_{2n}-t_{2n-j+1}$ and t_j-t_1 are chosen to be equal, Fig. 2 shows that the ratio R is unity to at least the same degree of accuracy that a linear approximation to $g(t)$ is valid over the interval $t_{2n}-t_1$. The linear approximation involved here is not the first term of a Taylor expansion about any point, but rather the chord that intersects the curve $g(t)$ at t_1 and t_{2n}. If the scanning

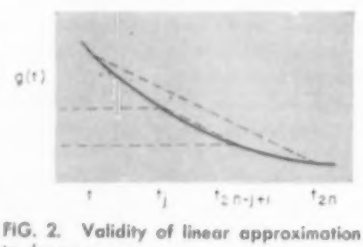
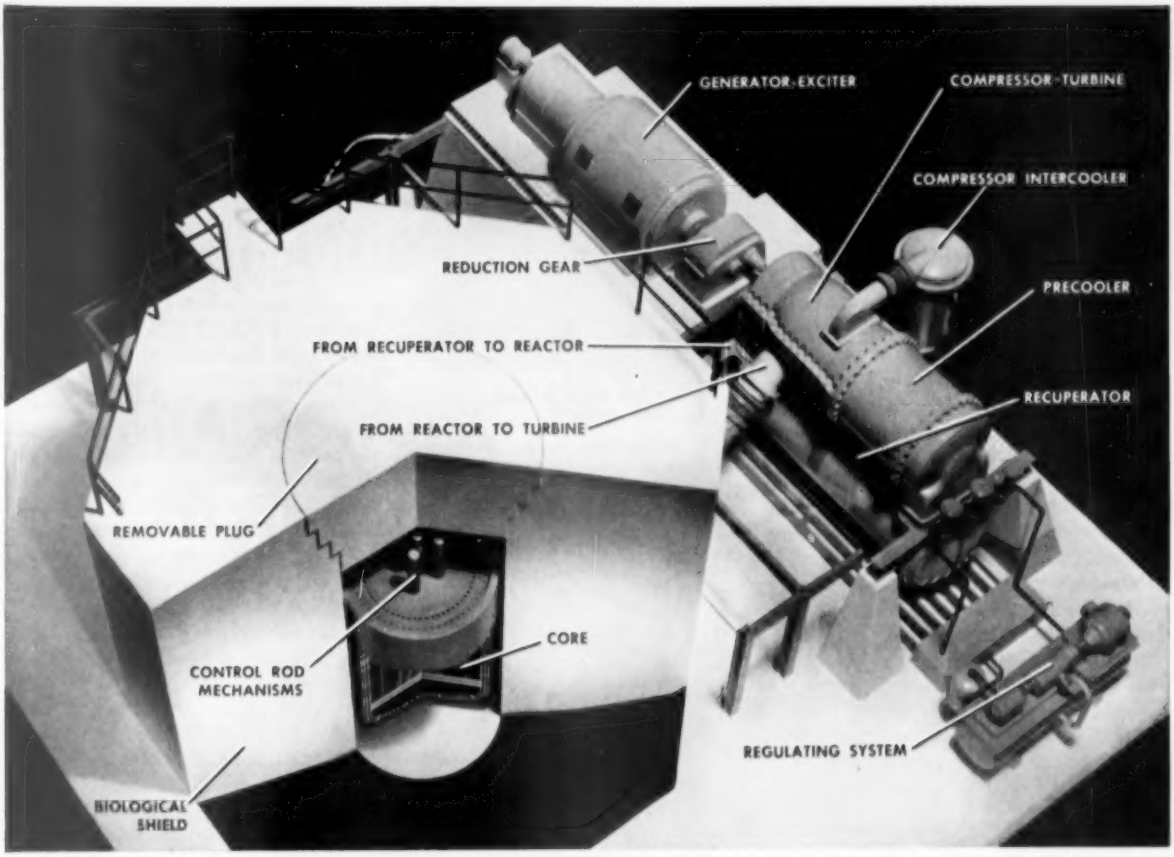


FIG. 2. Validity of linear approximation to decay curve

* Operated by the General Electric Company for the U. S. Atomic Energy Commission.



Model of a closed-cycle gas-cooled reactor power plant designed by Ford Instrument in conjunction with American Turbine Company.

THE CLOSED-CYCLE GAS-COOLED REACTOR
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What Is It? The Closed-Cycle Gas-Cooled Reactor is a reactor whose principle of operation is based on the concept of the use of a gas under pressure as the working fluid for *direct* transfer of energy from the reactor to a turbine. The gas used is nitrogen, carbon dioxide or helium. The closest analogous commonly known reactor type is the "boiling water" reactor.

Ford Instrument Company's Position: Ford Instrument has been conducting studies into the nature and prospects of this type of reactor and believes it to have many advantages as a nuclear power source.

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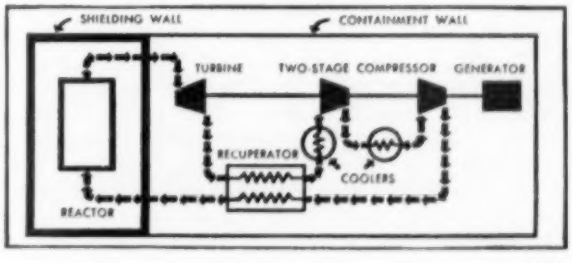
3. *High* power capacity. The study indicates that power capacity can be over 200 megawatts (output) from a single unit.
4. *Extreme* simplicity of operation.
5. *Maximum* safety. The nature of the working fluid used, with its freedom from phase change, means that provisions for containment in the event of an "incident" are simple, and that protection against incidents is simultaneously enhanced. The closed-cycle design precludes contamination of the atmosphere.
6. *A minimum* of moving parts. In this design, pumping power is provided by a turbo-compressor set, and no other pumps are required.

For more information on this new type of reactor write Ford Instrument Company.



A SCHEMATIC OF THE CLOSED-CYCLE GAS-COOLED REACTOR

101

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cycle is made short enough, one may then assume $R = 1$ and take the ratio of counts in the two channels as a measure of the ratio $f(x_j)/f(x_i)$.

When counting uranium strips, the scanner is set to read at ten separate points, counting for 30 seconds at a time. Thus a complete back-and-forth "scan" requires $2 \times 10 \times 30$ seconds = 10 minutes, except for the small additional time consumed in moving between points. Examination of the empirical decay curve has shown that the linear approximation to $g(t)$ introduces an error of only 0.5% in considering the relative activity of the two extreme ends of a fuel sample when a single 10-min scan is taken 35 min after "scram" following an irradiation time of 30 minutes. Of course, the relative error introduced on subsequent scans or for points closer together in the sample is less.

In measuring activities that decay exponentially with time, the requirements on the scanning cycle (so that the correction for the time decay during scanning be sufficiently accurate) are particularly simple. Here the ratio R as applied to the two extreme ends of the sample becomes

$$(1 + e^{-\Delta/\tau})/2e^{-\Delta/2\tau} = \cosh(\Delta/2\tau)$$

where $\Delta = t_{2n} - t_1$ is the time required for a complete scanning cycle and τ is the mean life of the activity being observed. Thus, for a time decay correction accuracy of δ or less, the condition is

$$\cosh(\Delta/2\tau) \leq 1 + \delta$$

or approximately

$$(\Delta/\tau) \leq 2\sqrt{2\delta}$$

That is, for an accuracy of 0.5%, the scan time should be no more than ½ of the mean life of the activity measured.

Resolution

To insure that the counts recorded in the jth channel represent a true measure of the relative radioactivity at the position x_j, it is necessary that the counter be well shielded and collimated. For this reason beta counting is preferable to gamma counting.

The ability of the scanning technique to reproduce details and sharp gradients in the power distribution was tested by scanning the end of an activated strip of enriched uranium. Figure 3 shows the measured power distribution, which ideally would vanish to the right of the point $x = 0$, at which the end of the sample reaches the center of the collimating window. Using a slit 1/16-inch wide, the contribution at the point $x = +0.5$ inch is only 2% of the "plateau," and falls off fairly rapidly at larger distances. One could, of course, reduce this background relative to the counting rate due to the portion of the sample seen by the slit by simply widening the slit, but then one would not be able to follow details in the flux pattern over distances shorter than the slit width.

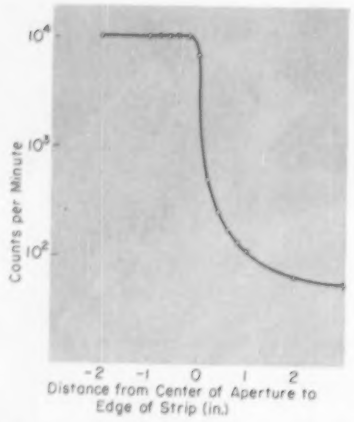

FIG. 3. Measured power distribution across edge of activated strip

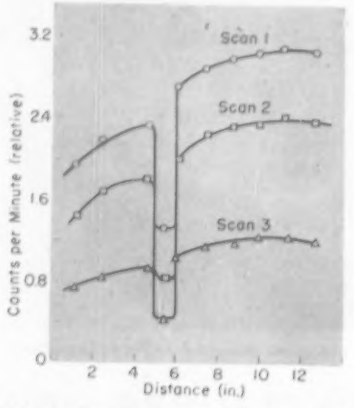

FIG. 4. Reproducibility of data. Successive scans of gold foil. Center portion was cadmium shielded during irradiation

Reproducibility of Data

The reproducibility of the counting method is shown by the data represented in Fig. 4, which shows the results of successive scanning of the same sample of 0.001-in. gold foil irradiated with a cadmium shield 1-in. long. To demonstrate the long-term stability of the counting equipment, the curves were taken in the order in which they are numbered with intervals of about 2 days elapsing between the end of one scan and the beginning of the next.

The simplest procedure for comparing two sets of data $f(x)$ and $g(x)$ taken on the scanner at different times is to "normalize" one set of data to the other by multiplying the curve $g(x)$ by the weighted mean of the ratios $f(x_j)/g(x_j)$. If one rather arbitrarily weights these ratios by the number of counts $g(x_j)$ in that particular channel, the weighted average of ratios reduces simply to $\Sigma_j f(x_j)/\Sigma_j g(x_j)$, which is the ratio of the total number of counts in the two sets of data.

After the entire curves are normalized in this manner, the scatter of the points is represented by an average standard deviation of 0.6%. A similar test using a strip of irradiated enriched uranium with intervals of 5 minutes between each successive scan gave an internal consistency of 0.7%.

To test the over-all reproducibility of the method, two uranium strips were laid back-to-back and irradiated in a reactor. After each strip was scanned twice and the resulting four curves normalized, the average scattering of the individual points was represented by a standard deviation of 1.1%, showing the contribution from nonuniformity of the samples. In general, the accuracy of results is limited by the uniformity of the strips or wires used and the accuracy of positioning them in the reactor and in the scanner.

Applications

The scanner has been used extensively for measurement of neutron flux in low-power experimental reactors. Figure 5 shows the fission-flux distribution along a radial traverse through a reactor of intermediate spectrum with alternate reflector materials. An absolute measurement of

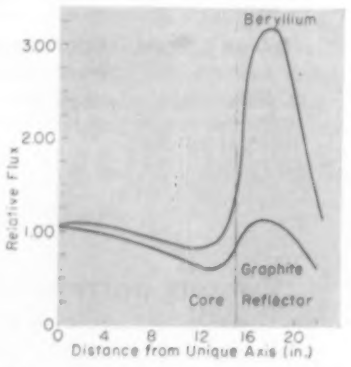

FIG. 5. Power gradients at core-reflector boundary of intermediate-energy reactor

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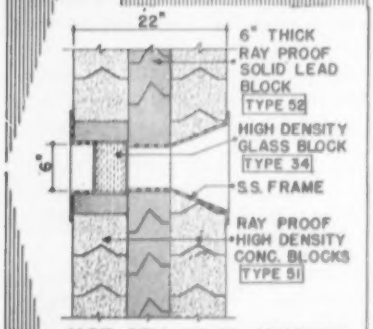

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neutron flux in the center by conventional methods (using standard foils) together with a number of traverses through the reactor permits calculation of the ratio of central-to-average power, and the total number of fissions in the reactor. From the relation 1 watt = 3.1×10^{10} fissions, one obtains the reactor power at levels below the limit of calorimetric measurements.

The device also has been used to measure the activity induced in cadmium-shielded fuel samples that, in conjunction with fission-flux distribution curves taken with the aid of bare foils, yield point-to-point fuel-cadmium fraction values.

Another application of the scanning technique is in the determination of steep power gradients occurring, for instance, at a control rod boundary or at the core reflector boundary (see Fig. 5).

The scanner also can be used to determine the activity induced in thin strips of resonance absorbers (indium, gold, tungsten, manganese) by an intermediate-energy flux. The spatial dependence $f(x)$ recorded in this case can be used together with corresponding reactivity coefficients to calculate the iterated fission probability F_L for the reactor (*2*, *3*). Similar measurements of cadmium-shielded and self-shielded (triple) strips of resonance absorber serve to determine the neutron spectrum throughout an intermediate-energy reactor.

BIBLIOGRAPHY

1. W. Bernstein, E. H. Foster, J. J. Floyd, Neutron flux scanner, AECU-1621
2. H. B. Stewart, NUCLEONICS **11**, No. 5, 38 (1953)
3. H. Hurwitz, Jr., R. Ehrlich, Paper P/608, "Proceedings of the International Conference on the Peaceful Uses of Atomic Energy," Vol. 5, (United Nations, New York, 1956)

Automatic Period Control of the Raleigh Research Reactor

By HAROLD A. LAMONDS
Physics Department
North Carolina State College
Raleigh, North Carolina

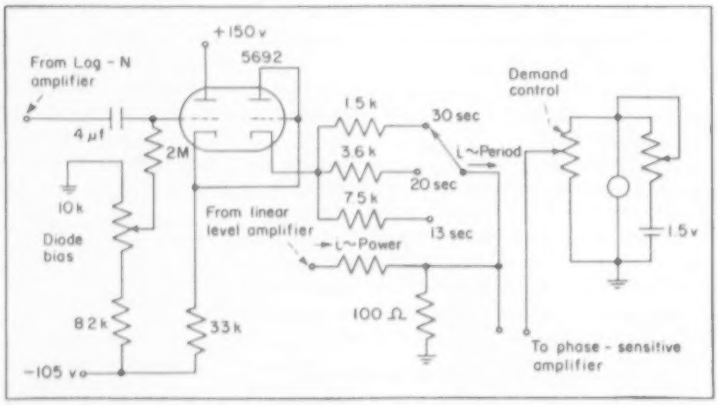
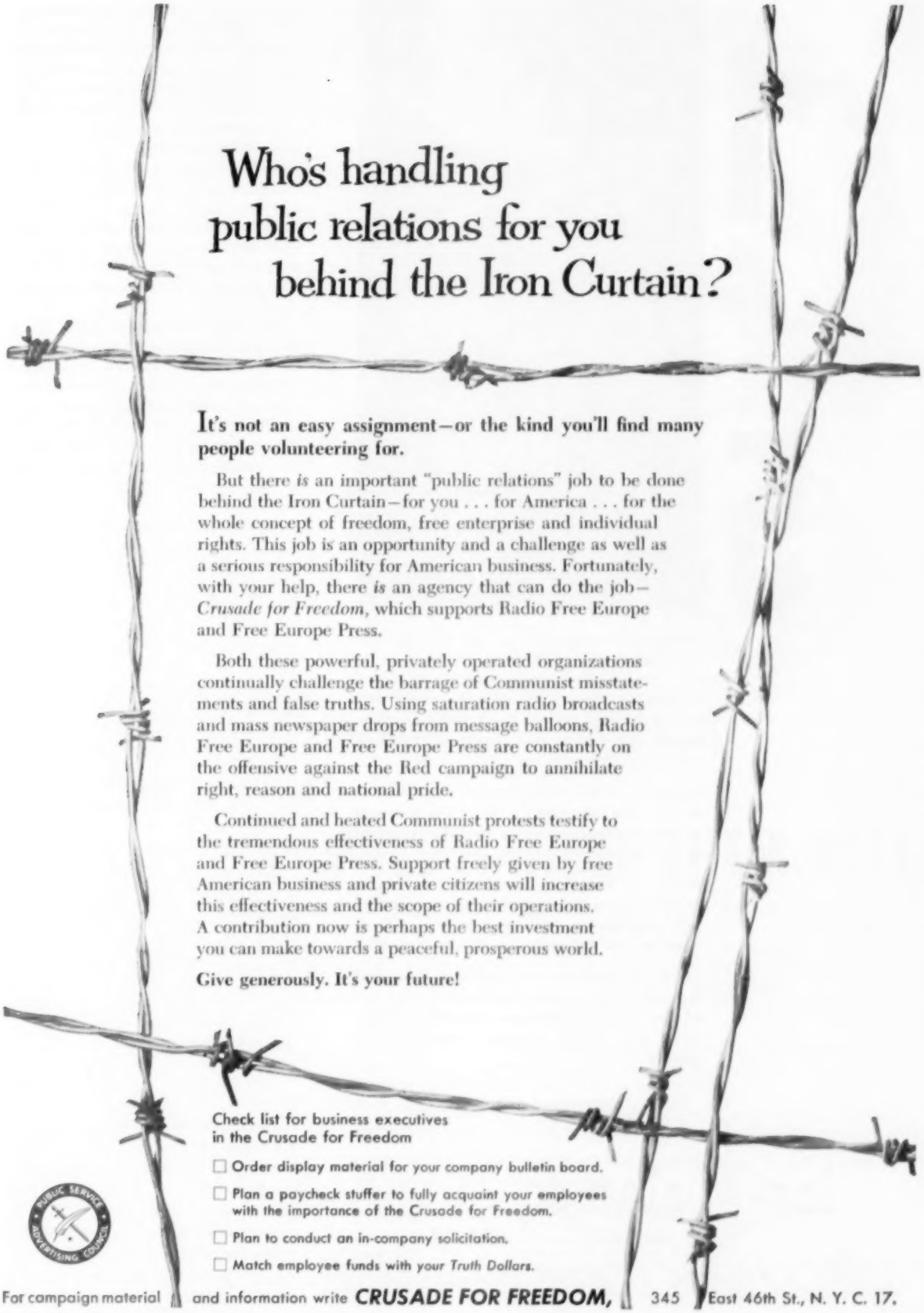


FIG. 1. Automatic period control circuit

A special electronic circuit—part of the control system of the Raleigh Research Reactor—permits the reactor to be brought automatically up to any desired level of operation on one of several preselected periods. When the desired power level has been reached, the automatic control system "takes over" to hold the level constant. This unique specially designed circuit, called the "automatic period control," is described here.

Need for Automatic Control

Before the automatic period control was installed on the Raleigh reactor,



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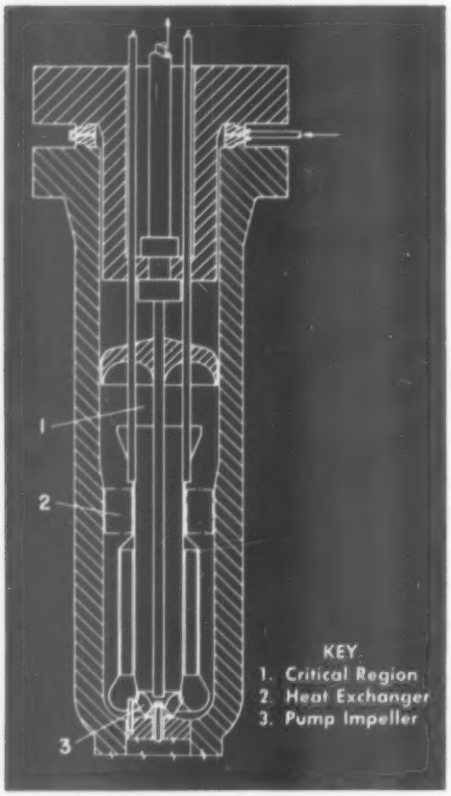

This simplified drawing of an experimental homogeneous type power reactor, now in the final assembly stage, shows one of five nuclear reactor projects currently under way at Los Alamos, where the world's first homogeneous reactor was designed and built and is still in operation.

Indicative of the importance of these experiments is the Laboratory's thirteen year record in active research, design and development in this major field of basic scientific interest.

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power level was changed by switching the control system from automatic to manual control, and the control rod was positioned manually to provide a safe period during the transition to the desired level. As the new power level was approached, the operator could either start manually to reposition the control rod to the critical position or he could set up the new demand level on the servo system and switch to automatic control as the new level was reached. These procedures usually resulted in an overshoot of the desired power level or an unnecessarily slow approach to it.

If a desired change in power level was small, an alternate procedure could be used. This consisted of simply changing the demand level and allowing the reactor to change power while on automatic level control. The inherent limitation imposed by the system on this means of changing power is indicated by a brief description of the automatic level control system. The servo system, which maintains a constant power level during normal operation, compares the amplified output of a neutron-sensitive chamber in the reactor reflector with a demand signal set by the operator (from a variable potentiometer). The error signal thus formed (i.e., the difference between these two) is fed into a phase-sensitive servo amplifier that energizes the rod drive motor to move the rod in such a direction as to reduce the error signal.

When a change in demand suddenly is fed into the servo system, the rod drives in the appropriate direction until the new demand level is reached and then starts to return to the critical position. If the change in demand were for a large increase in power, the rod could drive out far enough to result in a dangerously short period before the new power level was reached, in which case the reactor would be shut down by the automatic period safety trips. Even if the period should not become short enough to result in a shutdown, there would be an overshoot in power while the rod returned to the critical position. This would happen even though the overshoot is minimized somewhat by the delayed neutrons.

Consideration of control-rod effectiveness as a function of position points out another possible problem connected with changing power level. The control-rod position versus δk curve exhibits the familiar s-shaped characteristic. That is, near the extremities of its motion, the control rod must be

moved much farther to yield a given δk than is required near its central position. Thus, if the reactor were heavily loaded or the shims incorrectly set, resulting in a control-rod critical position near the upper end of its range, a largely increased demand in power would cause the rod to drive fully out before the new level were reached. In this case the added δk might not be sufficient to cause a period scram, but the overshoot might be very great due to the relatively long time required for the rod to drive in to the critical position once the new level were reached.

Thus, it is clear that it would be advantageous to incorporate into the control system features that would allow the power level to be changed at a fast but safe rate while eliminating overshoots or slow approaches to the new power level. These features are achieved by the use of automatic period control.

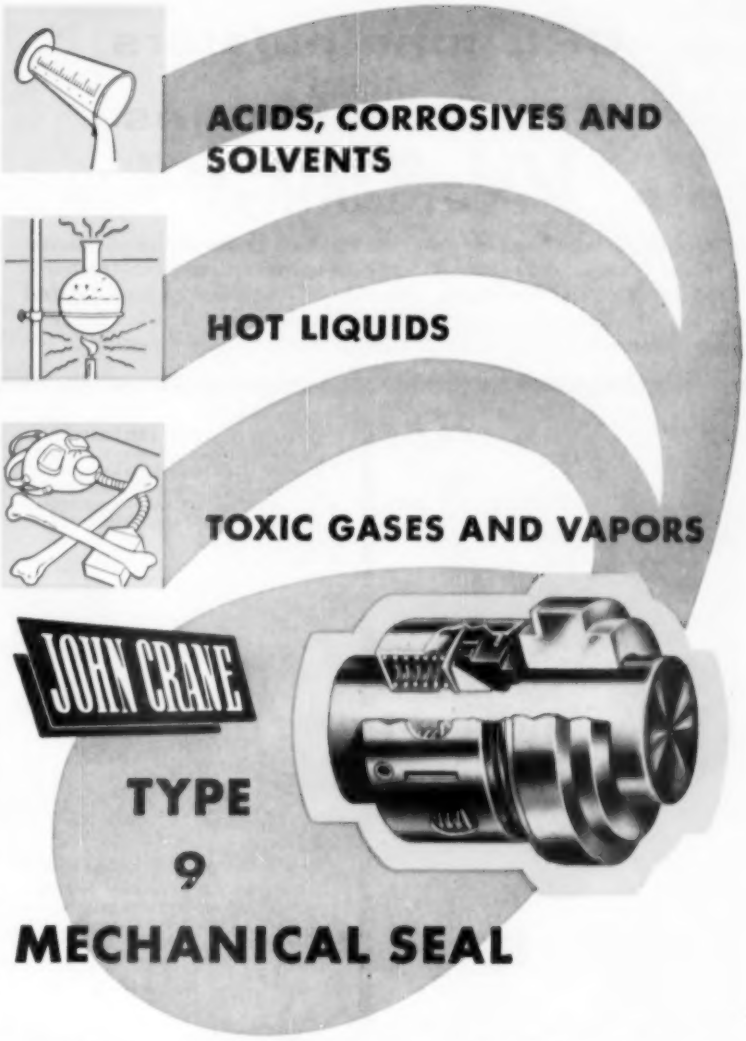
Basis for System

Most desirably, increases in power level are *exponential* rises. Such rises are obtained, after a short transient, from constant positive δk's corresponding to fixed rod positions (above critical). Thus, for a rise on a constant period, the rod remains stationary while the power increases exponentially (if thermal and other effects are not present). Exponential rises also allow large changes in power to be accomplished safely in a short time; similar changes in level could not be achieved linearly without reaching dangerously short periods.

To achieve a change in power level automatically at a constant period, a signal proportional to the period or to some simple function of it must be fed into the servo system. Since the period is infinite for constant-level operation, it is not feasible to use a proportional signal. An inverse-period signal, on the other hand, provides the needed qualities to tie in simply with the existing level control. That is, the signal is zero for steady-state operation and increases with decreasing period.

Such signals can be obtained by differentiating the output signal from the log N neutron-measuring channel with a simple RC circuit. The output voltage of the log N amplifier* is proportional to the logarithm of the current from a neutron-sensitive chamber in

* W. H. Jordan, H. B. Frey, George Kelly, ORNL-110 (1948).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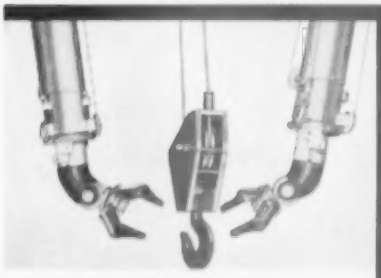

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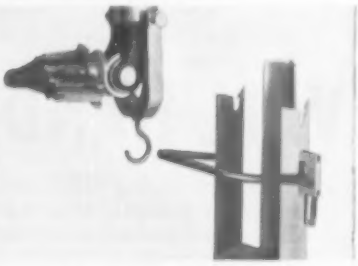

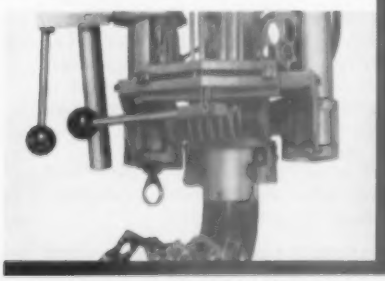

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the reactor reflector. This voltage may be expressed as

$$V = K_1 \ln K_2 i \qquad (1)$$

If the reactor is increasing in power exponentially, the chamber current may be written

$$i = i_0 e^{t/T} \qquad (2)$$

where T is the period. Thus the output voltage of the log N amplifier will be

$$V = K_1 \ln K_2 i_0 e^{t/T} = K_1 \ln K_2 i_0 + K_1 t/T \qquad (3)$$

If this is differentiated by an RC network, the current i_R flowing in the resistor R is

$$i_R = C(dv/dt) + i_2 e^{-t/RC} \qquad (4)$$

or

$$i_R = (CK_1/T) + \text{a transient term} \qquad (5)$$

Thus, the current flowing in the resistor of the RC network is proportional to the inverse period of the reactor after the transient term has dropped out. In this system the transient term may be neglected since it rapidly approaches zero in the circuit used. The current, i_R, is proportional to the capacitance used in the differentiating network, and thus the current obtained for a given period can be controlled by varying the value of C. This has one limitation in that the larger the value of C, with other factors constant, the longer is the time required for the transient term in Eq. 4 to become insignificant.

In the servo system to which this circuit is being applied, the current needed is rather large (1 ma); thus a simple cathode follower current amplifier is used as shown in Fig. 1. The voltage present at the cathode of the tube then can be considered essentially proportional to the inverse period. In achieving automatic period control of the reactor, this voltage is added in a simple summation circuit to the signal from the neutron chamber, which is proportional to the reactor power. The sum of the power and inverse-period signals then is compared with the demand signal set by the operator. This then is the error signal that is fed into the servo amplifier that energizes the rod drive motor.

The process of adding the power and period signals constitutes an important safety feature of the system. In fact, a period control that did not add the signals would be more straightforward, but would involve the risk that a not-too-alert operator might start a power

rise on automatic period control and fail to switch over to level control before the reactor had reached a dangerously high power level.

Operation and Performance

The complete control system performs as follows. When the reactor is operating steadily at the demand power level, the period is infinite and thus the inverse-period signal is zero. In this case, the demand signal is balanced by the power-level signal (from the neutron chamber) exactly as if the automatic period control were not in the system.

If the demand signal is increased significantly, the power-level signal appears to be very small and may be considered to be initially zero. Thus, the control rod drives out, causing the period to become shorter. When the period becomes short enough for the inverse-period signal to balance the demand, the rod does not move farther. In this position a constant period is maintained until the reactor power approaches the new demand level. As this happens, the power-level signal is no longer negligible and thus, to maintain balance in the servo system, the inverse-period signal must decrease at the same rate as the power signal increases. That is, the rod drives in so that the period approaches infinity as the reactor power approaches the new demand level. When the new level is reached, the period has become infinite, so no overshoot in power level occurs.

Since the operator may wish to change power on different periods, it is convenient to provide a switch by which various fractions of the signal appearing at the cathode of the current amplifier can be selected. Thus, for a given demand level, each switch position corresponds to a definite period. In the Raleigh reactor system the demand signal chosen for correct reading of the period-selector switch was arbitrarily chosen as 50% of the power-level range in use. This setting is acceptable normally since the power-level ranges are switched by factors of 2, 5, and 10, so any desired level will usually be close to 50% of some available range.

Figure 2 shows the reactor's power-level response to a step increase in demand by a factor of 500. The automatic period control was set for a 20-second period. Note that there is no overshoot. The same test cannot be performed on the reactor without period control since a period short

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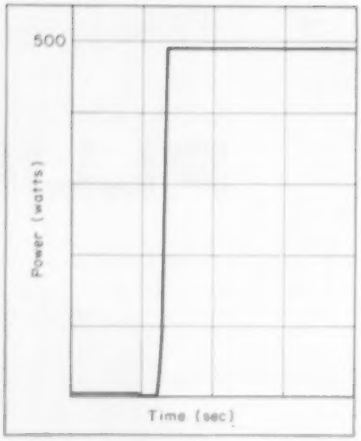


FIG. 2. Response of reactor power level to step increase in demand by factor of 500 with automatic period control

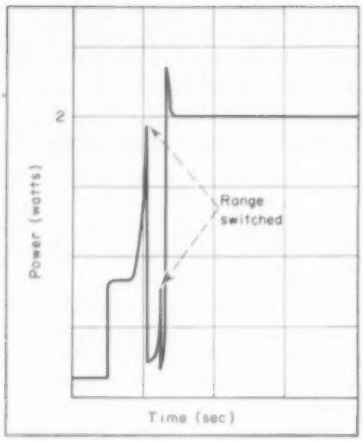


FIG. 3. Overshoot produced when reactor power is increased manually and switched to automatic level control at desired power without automatic period control

enough to cause an automatic shutdown would quickly be reached.

Similar tests can be done for small increases in demand, however, and their results point out the improvement effected by period control. For example, a step increase in demand by a factor of 1.5 results in approximately 1.7% overshoot. If demand is increased by a factor of 2, overshoot is 3%.

If, on the other hand, the reactor is brought up manually on a constant period and switched to automatic when the desired power level is reached, an overshoot still must result. Figure 3 illustrates the overshoot when this is done. The pile was brought up on a 20-second period; the resulting overshoot was 14%. The figures are only representative since the actual overshoot depends on the period, the magnitude of the power change and the rod excursion from the critical position.

In any operation of a reactor, adequate safety precautions must be observed. It is important therefore that backup safety circuits be provided to prevent a hazardous condition in case of failure of the automatic period control. The shortest period provided by the period selector switch is 13 seconds. If for some reason the reactor period should become as short as 10 seconds, an override circuit is provided in the control system; this drives the control rod in until the period becomes longer than 10 seconds, even if the operator or automatic control system is attempting to withdraw the rod. If, for any reason, the period continues to get shorter until it reaches 5 seconds, two independent period-safety trips operate to drop the rods and shut down the reactor.

The differentiated log N signal is relatively noisy; therefore, diode coupling is used between the period-current amplifier and the summation network. This effectively decouples the noise from the level-control circuit when the reactor is operating at a steady level. Thus, smoother operation is obtained at steady levels, and the possibility of rod drive-out due to a negative period transient is removed.

The inclusion of period control into the automatic control system of the Raleigh reactor has resulted in increased stability and safety. The simplicity and speed with which power level changes can be made with complete safety further reduce the need for dependence on human judgment for safe operation of the reactor.

* * *

The work described here was financially supported in part by the Office of Ordnance Research.

REACTOR FACTS

Aircraft reactor is air-cooled. High operating temperatures, relatively low pressures, and light weight are features of an air-cooled ANP test-stand reactor now in the detail design state. UO_2 fuel is in stainless-steel sandwich plates that operate at up to 1,800° F. Water thermalizes neutrons. Limitations are: low heat-transfer coefficients, induced radioactivity in cooling air makes turbines operate "hot," air-circulation costs are high, and successful operation is not proven.

TECHNICAL ADVANCES

Radiation Effects Aid Drug Bioassay Radiation is being used to stress animals before exposure to new drugs whose biological effects are being investigated. With this technique one can uncover potential blood-damaging effects, a matter of importance to pharmaceutical manufacturers. Purely chemical techniques cannot provide this information.

The unique procedure, developed by a group at New York University under H. A. Charipper, calls for sublethal doses that lower the white-blood-cell count because of damage to the blood-producing system. If the drug under test delays the postirradiation return to normal blood count the implication is that the drug inhibits blood production too.

Specifically, 10-week-old Long-Evans rats weighing 180–200 gm are exposed to 600 r at the rate of 15 r/min of filtered 200-kev X-rays. On the fourth day after irradiation, when the white blood count is at its lowest, the drug is administered. The drug is administered on each of the next five days and the blood count followed; then the drug is stopped, but daily blood counts continue for another week. If at the end of 14 days the recovery of the total white blood cells of the drug-treated animals was less than 60% of that of irradiated but undrugged controls, the drug is regarded as adversely affecting white-blood-cell production.

That this is of more than academic interest is further attested by the fact that Nuclear Science and Engineering Corp., Pittsburgh, Pa., is preparing to offer this test as a commercial service.

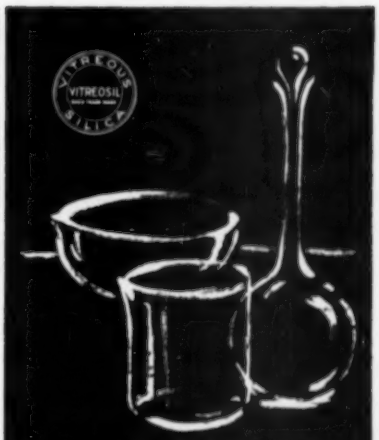
Extinct Activity: New Dating Tool? Stable daughter elements of extinct naturally radioactive nuclides (those with half-lives too short to have survived to this day) may provide a clue as to the age of rocks in which they are found and perhaps date the elements themselves. Of course, the half-life must not be so short that the activity would have substantially decayed away in the interval between the creation of the universe and the condensation into rocks—for it would then be impossible to distinguish the true nuclide distribution established in the earliest history of the universe. Truman Kohman, who presents these considerations in an article in the *Annals of the New York Academy of Sciences*, **62,** Art. 21 (March, 1956) sets the necessary range of half-lives as 3×10^7 to 3×10^8 years.

There are no known radionuclides with half-lives in this range. This is not unreasonable. The upper limit is explicitly chosen to insure that there be no substantial radioactivity currently observable. On the other hand, the long half-life makes for low specific activity when the radionuclide is formed as the product of an artificial nuclear bombardment.

Still, there is reason to believe that they exist. Kohman offers stability arguments to narrow the possible candidates. In particular negatron emitters undergoing third-forbidden transitions of high energy or second-forbidden transitions of low energy might have the sought-for half-lives. Similarly, first-forbidden electron-capture transitions of very low disintegration energy and second-forbidden transitions of moderate energy might fill the bill.

An experimental program is underway at the Carnegie Institute of Technology to find extinct natural radionuclides. One aspect of the program involves trying to produce artificially those nuclides for which one expects appropriate lifetimes on theoretical grounds. The second aspect is the isolation of their stable daughters from materials that may have contained such extinct radioactivities. The combination of known half-life and measured isotopic abundance can provide an accurate dating tool if several other criteria are met. In any event, our understanding of nuclear geology and the rarer nuclear species is sure to benefit.

Self-Inspecting Monitor System A monitor that monitors the monitor as well as the system monitored looks promising for nuclear applications. In principle the device periodically exposes the sensitive element to a simulated "unsafe" condition. The safe-unsafe square wave is required to hold the alarm-system relay open. Any failure in monitor or system sounds the alarm. Scully Signal Co. of Melrose, Mass. is the manufacturer.



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Carbon-14 Method Tests Home Laundering Procedures

By FLORENCE EHRENKRANZ* and EMIL H. JEBE*
Iowa State College, Ames, Iowa

The primary objective of this investigation was to develop a carbon-14 labeling method that would measure the relative effectiveness of different home laundering conditions on soil removal. The gravimetric method—difference in weight of washed and soiled samples—is unsatisfactory because washed samples often weigh more due to buildup of soap or detergent. The reflectance method (*1, 2*) measures only one soil component, carbon black, which is added to the soiling agent so that reflectance data may be obtained with a conventional instrument.

Preliminary Studies

Preliminary work was carried out by one of the authors (F. E.) using the aqueous-alcoholic extract of the leaves of a plant grown in an atmosphere of $C^{14}O_2$.† A benzine solution of the extract did not give a sensitive measure for the relative effectiveness of different laundering procedures. An oil solution of the extract was more effective.

However, the extract contained numerous components that might respond differently to the same washing conditions. A soiling agent having only one radioactive component seemed desirable. Also, since the results would be valid only for the soiling agent used, a soil of practical importance in home laundering was desired.

Other workers have described three somewhat complex, labeled soiling agents not easily obtained (*3*). For the investigation described below, labeled tripalmitin was selected because common soils on cotton clothing and household textiles are likely to contain fatty materials such as triglycerides of oleic, stearic, and palmitic acids (*4*). Also, it is reasonable to assume that dry soils adhere to cotton fabric partly because of fatty materials.

Tagged Tripalmitin

The active material was carboxyl-tagged tripalmitin—glyceryl tripalmitate $(C_{15}H_{31}COO)_3C_3H_5$. Two ½-mc lots were obtained (Tracerlab, Inc., Boston, Mass.) with specific activities of 0.67 and 0.56 mc/millimole. One ½-mc lot was dissolved in 200 ml of benzene as a master stock.

Thirty soil swatches were prepared for each day's washes as follows. Approximately 3.7 ml of the master solution were transferred by Automatic Pipette (Kimball Glass Co., Vineland, N. J.) to a 10-ml Erlenmeyer flask. The benzene was evaporated by gentle heating and approximately 3.5 ml of U.S.P. olive oil were added to the flask. Since tripalmitin is a component of olive oil, it dissolved in the oil. Approximately 0.1 ml of the olive-oil solution was applied to each of the 30 swatches by means of the pipette.

The pipette did not insure equal quantities of the active solution on each swatch. Hence, the swatches were randomized as follows. The 30 white muslin swatches were coded from 1 to 30 and soiled in that sequence. Next, the ten swatches used in each of the three washes on a particular day were determined from a table of random numbers.

SOILING CLOTH SAMPLE with Automatic Pipette

TABLE 1—Mean Results of Selected Effects on Laundering Effectiveness

Effect	*Mean time difference of count times*	*Mean percent soil removed*
Over-all means	2.661	55.97
Replicate		
1	1.967	50.90
2	2.603	55.95
3	3.413	61.07
Machine		
1	2.634	56.28*
2	2.688	55.66
Temperatures		
120° F	2.425	54.30
140° F	2.742	55.95
160° F	2.816	57.67
Detergent-water†		
S_1	2.481	54.65
S_2	2.490	55.05
S_3	3.012	58.22

* The apparent difference in order of effectiveness of machines 1 and 2 as indicated by percent data and time data seems to be due to the application of a nonlinear transformation in obtaining percent data.

† S_1 is detergent and hard water; S_2, detergent and soft water; S_3, soap and soft water.

* Department of Household Equipment and Statistical Laboratory, respectively.

† The leaves of the soybean plant were obtained through the courtesy of Sam Aronoff, Iowa State College.

Sample preparation. The size of the swatches was determined primarily by the area that would be exposed to the end-window Geiger tube. Several hundred $2\frac{3}{4} \times 2\frac{1}{16}$-in. swatches were cut from two new, washed, muslin bed sheets.* Three small holes were stamped in each swatch to engage studs on the lead plates used in soiling and in the Geiger tube housing.

The holder for soiling consisted of two lead plates. Both plates had 1-in.-diameter center holes. Also, the bottom plate had three studs and the top plate matching holes for the studs. The swatch was placed over the studs on the bottom plate and the top plate held it flat. The soiling solution was applied at the center of the one-inch hole in the top plate (Fig. 1).

The swatches were dried in vacuum and then hung on wires in a large, partly covered box at room temperature for three days. (A three-day "aging" of the soiled swatches was used, because this was the minimum aging that gave approximately stable initial counts.) On the fourth day the activities of the soiled surfaces of the swatches were counted. Next, the swatches were washed. After washing, the swatches were air-dried for two days and their activities counted again.

Counting. The sample holder for the G-M tube housing was another lead plate. The holder had a screw on its rear surface and three studs on its top surface. The screw served as a stop when the holder was put in the slides in the tube housing. The studs contacted the front half of the end of the tube. The swatch was placed over the studs and secured by Scotch tape. The tape was used to insure flat fit to the holder after washing, since samples may be wrinkled during the washing process. The distance between sample and tube window was approximately 2 mm.

Initial and final counts for swatches and background counts were made with a Tracerlab TG-2 G-M tube and utility scaler provided with timer. Times to reach a total count of 6,400 were recorded for soiled and washed samples (about 2 min and 3.5–7.8 min., respectively). The difference in counting

* The use of two sheets, both washed, but one desized and the other not desized, was associated with differences in replications.

TABLE 2—Analysis of Variance of Counting-Time Differences*

Source of variation	*Degrees of freedom*		*Sum of squares*	*Mean square*
Main plots		5		
Replicates	2		188.96	94.48
Machines	1		0.39	0.39
Machine error (*a*)	2		0.70	0.35
Split plots		48 (within main plots)		
Days†	12		265.97	22.16
Detergent-water (*S*)	2		33.34	16.67
Temperature (*T*)	2		15.49	7.74
Interactions‡				
S × temperature	4′		2.87	0.72
S × machine	2		0.45	0.23
Temperature × machine	2		0.34	0.17
(*S* × *T*) × machine	4′		3.62	0.90
Split plot error (*b*)	20		40.98	2.05
Subsampling error§		486	142.12	0.29
Total		539	695.23	

* Application of the analysis of variance to these differences seems reasonable (*5*, *6*). Further investigations of the authors indicate that logarithms of the time differences should yield a more appropriate analysis. Such an analysis was completed and gave results essentially identical with Table 2.

† The day effect is measured within replicates and within machines. With 18 days, total degrees of freedom are 17, but 5 have already been isolated for the main plots above.

‡ Due to the partial confounding, the primed interaction effects, e.g. 4′, are estimated from only parts of the data.

§ The subsampling error is measured among swatches of the same machine load, all receiving the same treatment. Ten swatches in each load give 9 degrees of freedom for each of the 54 loads washed.

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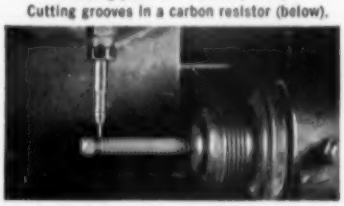
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time before and after washing provided a measure of the amount of soil removed.

Household Washers

The factors selected for investigation were two household washers of different makes; water temperatures of 120, 140, and 160° F; soft wash water with soap, soft wash water with detergent, and hard wash water with detergent.

Three loads of 36 pieces each of desized cotton (Indian Head) rectangles 20 × 32 in. were assembled. Each load weighed approximately 7.3 lb. One load was used for the soft-water washes with soap, another for the soft-water washes with detergent, and the third for the hard-water washes with detergent. As stated earlier, ten soil swatches were used for each washing test. One end of a soil swatch was stapled to the center of a large rectangle. The 26 rectangles that did not have attached swatches functioned solely to simulate a household wash load.

The water supply for all the washes was a college well. The hard well water averaged 24–25 grains calcium carbonate equivalent per gallon of water during the period required for the experiment. Soft water (0–0.5 grains/gallon) was obtained by passing hard water through a household-size zeolite water softener. The concentrations of the high-sudsing built detergent in the wash water was 0.14% for soft water and 0.40% for hard water. The concentration of the built soap in soft water was 0.20%.

The regular cycle of the household washers was used with a 10-min wash time. At the end of the cycle, the swatches were removed from the large rectangles and air-dried. The swatches were used once only.

Experimental Design

Several considerations influenced the choice of the experimental design. All articles are not washed uniformly in household washers (*1*, *2*). Also, over the several-months duration of the experiment, G-M tube characteristics might change.

Further, the experiment involved three factors: machine, temperature, detergent-water. The first factor, machine, had two levels; the other two factors had three levels each. This gave 2 × 3 × 3 or 18 treatment combinations. A factorial experiment in the completely randomized experimental

design, or the completely randomized block design, was not suitable because only three washes could be done per day, and variation in results might occur from day to day. It was decided, therefore, to limit the amount of information that would be obtained on the machine factor.

A general split-plot design was adopted utilizing three replicates. The 18 treatment combinations are complete in each of the three replicates. The machines are the main plots. The 54 wash tests are the split plots. On the split-plots, a partially confounded 3^2 factorial was imposed.* The temperatures and detergent-water conditions provided the nine treatment combinations within a machine.

Experimental Data

If experimental techniques were such that the initial count times exhibited considerable variation, final count times might be expected to vary correspondingly. A scatter-diagram of final versus initial count times of data from swatches receiving the same treatment seemed to indicate no relationship between final and initial count times. Hence, no adjustment was considered.

Variables analyzed. As a first measure of treatment effectiveness, the difference between final and initial count times, previously corrected for background,† was studied. Another variable of interest might be the percent of soil removed. This is a nonlinear function of the count times, $100\ (F - I)/F$.

Summary table. Table 1 gives the averages in two forms: (1) averages of the time differences for each swatch exposed to the effect indicated (final count time − initial count time), (2) averages of the percent soil removed from each swatch or $100\ (F - I)/F$.

It is usually desirable also to present two-way tables for combinations of the factors used in the experiment. The confounding employed in this experiment makes this somewhat difficult. Fortunately, as will appear from the analysis of variance below, the interaction effects were negligible. Thus,

* The partially confounded factorial imposed on the split plots is described in detail in Sec. 6.15, W. G. Cochran & Gertrude Cox, "Experimental Designs" (John Wiley & Sons, N. Y., 1950). Other sections of this text describe the general split-plot design.

† Because the background count was relatively low, analyses of the uncorrected time differences and corrected time differences yielded similar results.

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the means or percentages given in Table 1 effectively describe the results for the various treatments.

Table 1 shows that the over-all washing results improved from replicate one through three. The difference between replicates three and two probably is due to the fact that the cloth samples used in replicate two had been desized before they were soiled while the cloth samples used in replicate three had not been desized. Desized fabric is more absorbent than fabric that is not desized and the difference between replicates three and two seems to verify that desized fabric is more difficult to wash clean than sized fabric.

The difference between replicates two and one appears to be associated with the replacement of the original G-M tube when two-thirds of replicate two were completed. The initial counting times for the first two day's washes after the tube was replaced were low relative to previous initial counting times, while final counting times were of the same order of magnitude as previous final counting times.

Analysis and Interpretation

The analysis of variance (Table 2) provides the relevant information for assessing the differences among the factor-levels presented in Table 1. The reliability of a machine mean, i.e., its standard error, is measured by $1/\sqrt{k}$ times the square root of the machine-error mean square, where k is the total number of swatches used in each machine. Since this is $\sqrt{0.35}/\sqrt{270}$ or 0.036, the observed machine difference, 0.054 from Table 1, may be attributed to chance variation.* Finding no real differences among machines was not unexpected. The power of this experimental design was low for detecting a difference if, in fact, one did exist. Further, machines known to be quite similar were used in the experiment.

For the factorial treatments, sampling reliability is judged by use of the split-plot error (b) or 2.05 (Table 2). The split-plot error (b) represents the remaining variation among the 54 single wash tests after removal of the variation due to the systematic effects imposed in the experiments, e.g., the replicates, machines, days, treatments, etc.

Since each detergent-water condition

* This conclusion could also be reached by examining the observed F ratio for machines, $F = 0.39/0.35 = 1.11$, and referring this to the tabular value $F_{0.05(1,7)} = 18.51$.

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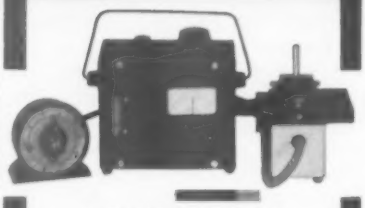

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and each temperature was observed for a total of 18 machine loads with 10 swatches per load, the standard error of the means is $\sqrt{2.05}/\sqrt{180}$ or about 0.11. From the means of Table 1 and the observed F ratios of Table 2 (F = 16.67/2.05 for detergent-water conditions and F = 7.74/2.05 for temperatures), we conclude that this experiment shows real differences among temperatures and detergent-water conditions.* Specifically, detergent-water conditions S_1 and S_2 were about equal in effect, but S_3 did a significantly better job of washing. Similarly, 120° F was poorer than the two higher temperatures, but 140° and 160° F showed about equal washing ability (7). Further, each of the replications indicated the same order of effectiveness for the factors under investigation, i.e., 120° F inferior to 140° F and 160° F and soap with soft water superior to detergent with hard or soft water. The last finding appears to be reported here for the first time.

Two points on the efficiency of the experimental design are worth noting. (1) The deliberate partial confounding of days with temperature and detergent-water interactions has vastly increased the efficiency of the experiment in comparing the factorial treatment levels. The day's sum of squares, 265.97, if mixed with the split-plot error (b) sum of squares, 40.98, would have greatly increased the experimental error mean square for the factorial treatments. (2) The relative magnitudes of the split-error (b), 2.05, and the subsampling error, 0.29, can be used to determine an optimum number of soiled swatches per load for future experiments (8).

BIBLIOGRAPHY

1. F. Ehrenkranz, V. W. Hyatt, M. Beale, *Soap Sanit. Chemicals* **30**, No. 2, 46 (1954)
2. E. S. Ross, K. Taube, D. S. Greene, Home washing machines—operating characteristics and factors affecting performance, Technical Bulletin No. 1088 (U. S. Department of Agriculture, Washington, D. C., 1954)
3. J. M. Lambert, J. H. Roecker, J. J. Pescatore, G. Segura, Jr., S. Stigman, How to prepare and use radioactive soils, NUCLEONICS **12**, No. 2, 40 (1954)
4. C. B. Brown, Studies in detergency, I. The oily constituent in naturally occurring domestic dirt, *Research* **1**, 46 (1947)
5. A. Birnbaum, Statistical methods for Poisson processes and exponential populations, *J. Am. Stat. Assoc.* **49**, 254 (1954)
6. J. W. Tukey, Query 113, *Biometrics* **11**, 111 (1955)
7. H. O. Hartley, Some recent developments in analysis of variance, *Communications on Pure and Applied Math.* **8**, Sec. 1.4, 47 (1955)
8. W. G. Cochran, "Sampling Techniques," Sec. 10.6, p. 225 (John Wiley and Sons, Inc., New York, 1953)

* The tabular F value at the "5% level" is $F_{0.95(3,20)} = 3.49$. The observed F values for temperature effect and detergent-water effect exceed this figure.

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BOOKS

Control of Nuclear Reactors and Power Plants

By M. A. SCHULTZ (McGraw-Hill Book Co., Inc., New York, 1955, viii + 313 pages, $7.50). Reviewed by JOHN MACPHEE, American Machine and Foundry Co., New York, N. Y.

The publication of this book marks the first organized presentation of the problems confronting the nuclear-reactor control engineer. The text is intended for readers having a background in the field of servomechanisms and a basic knowledge of reactor physics. However, anyone associated with some phase of nuclear-reactor technology will find at least some portion of the book profitable reading.

Perhaps those who have only recently entered the nuclear field will be surprised by the philosophizing of the author, especially in the early chapters. However, because of the potential hazards of reactors and their association with more dramatic devices by the general public, philosophy in control is as important as technology.

If fault must be found with this book, it can be said that the author has restricted himself to heterogeneous thermal reactors cooled by a fluid in which no phase change is allowed. However, the reader who becomes well versed in the principles developed in the text should have no difficulty applying them to problems concerned with other reactor types.

Chapter 1 is an introduction that sets the stage for subsequent sections of the book. The two following chapters discuss the characteristics of reactors that describe them as control components. In keeping with the author's assumption regarding the reader's knowledge, the reactor kinetic equations are deduced or presented rather than derived. Solutions are presented for the response of the reactor to various aperiodic forcings and for various initial conditions. Fission-product poisoning, temperature, and other factors affecting reactivity are discussed. Finally the reactor transfer function, upon which many of the later chapters depend, is derived.

Chapter 4 considers the problem of controlling a nuclear reactor in which the effect of the load on reactivity is negligible. Inherent feedback resulting from fission-product poisoning and temperature variations is shown to modify the reactor transfer function. The section on feedback due to temperature variations should have been treated in greater detail. However, it is elaborated on in chapter 6. The remainder of chapter 4 is devoted to reactor-control-system design.

There are two chapters on components peculiar to reactors—chapter 5 on control rod drive mechanisms and chapter 7 on radiation detectors. The inclusion of this material was a wise choice since these components represent new fields in themselves.

Chapter 6 treats the problem of controlling a nuclear power plant. Here the reactor is only one of many components. A sample system is analyzed for stability using the frequency-response method. Also included are curves showing transient response to changes in load and reactivity. Having thus outlined the problem, the author concludes this chapter by discussing the requirements of the plant control system for different conditions.

Operational control problems are treated in chapters 8, 9, and 10 on start-up, power operation, and shutdown, respectively. These chapters, in particular, should appeal not only to control engineers but to everyone concerned with reactor plant design.

The book is concluded with a chapter on simulators.

Of additional value are the comprehensive lists of references that appear at the end of each chapter. Also included at the end of the book are problems arranged according to chapter.

The author has made an important contribution to the library of books on nuclear-reactor technology.

An Introduction to Reactor Physics

By D. J. LITTLER and J. F. RAFFLE (McGraw-Hill Book Co., Inc., New York, 1955, viii + 196 pages, $4.50). Reviewed by H. HURWITZ, JR., General Electric Co., Knolls Atomic Power Laboratory, Schenectady, N. Y.

Reactor physics is a large field to cover in less than 200 small pages, especially when one third of the pages are devoted to nuclear physics. Littler and Raffle have been able to cover their subject in this limited space by sacrificing profundity rather than clarity. Thus, although a critical reader might wish for a more precise expression of some of the ideas, he would usually be hard put to suggest an alternate presentation which was neither obscure nor more verbose than that employed by the authors.

The reactor theory discussion centers around the gas-cooled, graphite-moderated reactor type which plays a dominant role in the U. K. atomic energy program. Although this reactor type illustrates most of the important principles of reactor physics, there are some features of other reactor types (particularly highly enriched reactors) that do not come under consideration.

Since both the mathematics and physics are presented in a self-contained and elementary fashion, the book will be of use to students at an early stage in their training. The references, though not extensive, provide adequate suggestions for further reading. The emphasis given to nuclear physics and experimental techniques helps to provide the student with a balanced perspective of the field of reactor physics. For example, the chapter devoted to detectors brings to mind the fact that long ago someone had to learn to observe and study the particles that we nowadays take so much for granted.

The subject of radiation damage, which is often omitted from reactor physics texts, is covered in a short chapter that at least serves the purpose of introducing the terminology.

The book does not reflect the reactor physics information presented at the Geneva conference, possibly not so much because of the time of publication as because most of the new reactor physics information was of too detailed a nature to fit into a brief elementary text.

The authors have based their book on a series of introductory lectures that they delivered to the Harwell reactor school. A person who would like to attend such a series of lectures, but finds none conveniently at hand, could turn to "Introduction to Reactor Physics" as a satisfactory substitute.

BOOKS RECEIVED

Catalogue of Nuclear Reactors—1955. This catalog (AECL-220, CRR-590) was prepared by Atomic Energy of Canada, Ltd., Chalk River Project, and Atomic Energy Research Establishment, Harwell, England. It was compiled from the unclassified literature and refers to reactors known to have reached criticality by July '55. Information includes neutron speed and flux, fuel configuration, moderator, reactor purpose, thermal power, and construction details. References, which include Geneva conference pa-

pers, are only those that are more complete sources of information. *North America: The Scientific Document Distribution Office, Atomic Energy of Canada, Ltd., Chalk River, Ontario, Canada; United Kingdom: Her Majesty's Stationery Office, London, England; 4s. 6d. (about $0.63).*

Actions Chimiques et Biologiques des Radiations, edited by M. Haissinsky (Masson et Cie., Paris, 1955, viii + 252 pages, $8.00). This book is in three parts: Physical Aspects of Radiobiology (in French), by L. H. Gray; Radiation Chemistry of Aqueous Solutions, Present Appearance of Experimental Results (French), by M. Lefort; Modern Trends in Radiation Biochemistry (English), by W. M. Dale.

Atomkraft, by Friedrich Münzinger (Springer-Verlag, Berlin, 1955, vi + 94 pages, $2.50). The subtitle describes the book as a study of the technical and economic outlook for atomic power plants. The discussion covers gas-, metal-, and water-cooled reactors, heat-exchange and generating equipment; and competitive capability of atomic power.

Atomic Power (Simon and Schuster, Inc., New York, 1956, x + 180 pages, $1.00). This book is a collection of articles published in *Scientific American* in recent years. The articles are arranged in sections on reactors, resources, fuel and fission products, economics and politics, radiobiology, and the hydrogen bomb.

Titanium—Metallurgy of the Rarer Metals, 4, by A. D. McQuillan and M. K. McQuillan (Academic Press, Inc., New York, 1956, xix + 466 pages, $10.00). The basic properties of titanium and its alloys are fully discussed, together with the principles of production and processing on an industrial scale.

Modern College Physics, 3rd ed., by Harvey E. White (D. Van Nostrand Co., Inc., New York, 1956, xiii + 824 pages, $6.75). Atomic and nuclear physics have been brought up to date and 200 new problems added to this college physics book.

Éléments de Mécanique Quantique, by Ph. Pluvinage (Masson et Cie., Paris, 1955, xiii + 547 pages, $11.50—paper, $13.25—cloth). This introductory text to quantum mechanics consists of three parts: the particle in one-dimensional motion (Schrödinger equation, Heisenberg principle, etc.), the particle in space (orbital movement, Zeeman effect, continuous and discontinuous spectra, spin, fine structure, etc.), and conceptions of particulate systems (general quantum mechanical principles, helium atom, diatomic molecules, etc.).

Electronics and Electron Physics, Vol 7, edited by L. Marton (Academic Press, Inc., New York, 1956, x + 525 pages, $11.50). The topics included are semiconductor materials (Burstein, Egli), electrical properties of germanium and silicon (Brooks), energy losses of electrons in solids (Marton, Leder, Mendlowitz), sputtering by ion bombardment (Wehner), observational radioastronomy (Wild), analog computers (Vance, Hutter, Lehmann, and Wadlin), and electrical discharge in gases (Goldstein).

Temperature—Its Measurement and Control in Science and Industry, Vol. 2, edited by Hugh C. Wolfe (Reinhold Publishing Corp., New York, 1955, iv + 467 pages, $12.00). This contains the proceedings of the Third International Symposium on Temperature (Oct. '54), sponsored by the American Institute of Physics, the National Bureau of Standards, and the Office of Ordnance Research, U. S. Army. The 24 papers are on general concepts, standards and scales, transient phenomena, experimental measurements, and miscellaneous topics (atomic-explosion temperatures, ionization measurements at high temperatures, upper atmosphere).

Relativity—The Special Theory, by J. L. Synge (North Holland Publishing Co., Amsterdam, and Interscience Publishers, Inc., New York, 1956, xiv + 450 pages, $10.50). Relativity is presented in terms of the geometry of space-time. After restatement of the special theory, the author leads the discussion to Newtonian mechanics, elastic collisions of particles, and models of uncharged particles of finite energy and of protons constructed out of singularity-free solutions of Maxwell's equations in vacuo.

ALSO OF NOTE

Regulation of Radiation Exposure by Legislative Means (NBS Handbook 61). This handbook presents the problem of radiation in relation to its possible control by state or municipality. It is based on studies conducted by the National Committee on Radiation Pro-

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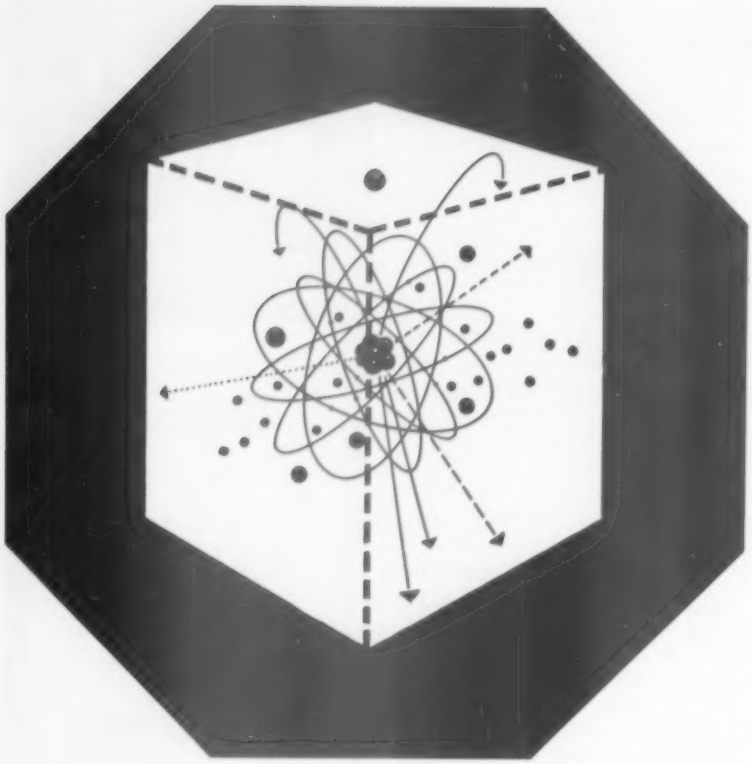

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Nuclear Level Schemes. This compilation (TID-5300) is a continuation of the effort to collect nuclear data, e.g., NBS-499. The present work is the first section of a series sponsored by the National Academy of Sciences—National Research Council and supported by the AEC. Decay schemes are drawn for all known radionuclides with masses 40–92 (Ca–Zr). Future sections will cover about 20 elements each. The organization of data differs from NBS-499—(1) all isobars of a given mass are presented on the same level scheme; (2) data are organized by mass number (A) rather than by charge number (Z). *Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., $1.75.*

Proceedings of the Conference on Effects of Radiation on Dielectric Materials (Publication PB111863). This '54 conference was sponsored by the Naval Research Laboratory and Office of Scientific Research, Air Research and Development Command. Topics covered are radiation effects on polymers, alkali halides, and nitrates, dielectric materials, glass, valence and ionic crystals, and organic materials. *Office of Technical Services, Department of Commerce, Washington, D. C., $4.25.*

101 Atomic Terms and What They Mean. This glossary explains technical terminology in a popular way. *Public Relations, Esso Research and Engineering Co., 15 W. 51st St., New York 19, N. Y.*

Bulletin of the Geological Survey of Great Britain, No. 10. The bulletin contains an article on carborne, radiometric surveying and three others on radioactive-mineral studies in England and Canada. *Atomic Energy Division, Geological Survey and Museum, Exhibition Rd., London, S.W.7, England.*

Tables of Thermal Properties of Gases (NBS Circular 564). This 478-page compilation, by J. Hilsenrath *et al.*, gives thermodynamic and transport properties of air, argon, carbon dioxide, carbon monoxide, hydrogen, nitrogen, oxygen, and steam. *Government Printing Office, Washington 25, D. C., $3.75.*

French Doctoral Theses, Sciences (1951–1953). Theses are listed in the biological, earth, and physical sciences according to author. A subject index

is appended. *M. André Gauvenet, French Embassy, 972 5th Ave., New York 21, N. Y. (no charge).*

Proceedings of the Ninth Annual Conference on the Administration of Research. This 107-page book reports the meeting at Northwestern University, Sept. '55. *New York University Press, Washington Square, New York 3, N. Y., $4.00.*

Soviet Research in Physics. Five collections are available of English translations of papers published in recent Proceedings of the Academy of Sciences of the U. S. S. R.: No. 1, nuclear physics; No. 2, nuclear and solid-state physics; No. 3, nuclear, low temperature, microwaves, and electromagnetic theory; No. 4, high-energy fission; No. 5, mass spectrometry, vacuum-tube technology, ferroelectricity, microwaves, quantum theory. The last three include translations of the titles in vols. 101, 102, and 103, respectively. *Consultants Bureau, 259 W. 14th St., New York 11, N. Y., $15.00 for each collection.*

The Geneva Atomic Papers. Over 1,000 papers presented at the Geneva conference are indexed by country and subject. *Whaley-Eaton Service, Munsey Building, Washington 4, D. C.,*

Radiation Chemistry for Industry. In nontechnical language, this book discusses the application of radiation to industry. Included are theory, developments in relation to chemicals and treatment of foods and pharmaceuticals, safety considerations, and future implications. *Radiation Chemistry Associates, c/o T. Lang Moffat, Apt. 207, 70 Clearview Heights, Toronto 9, Ontario, Canada, $7.50.*

Table of the Descending Exponential. This publication in the National Bureau of Standards Applied Mathematics Series 46 tabulates the negative exponential e^{-x} from $x = 2.5$ to $x = 10$ at intervals of 0.001 to 20 decimal places. *Government Printing Office, Washington 25, D. C., $0.50.*

X-Ray Protection (NBS Handbook 60). This handbook supersedes "Medical X-Ray Protection up to Two Million Volts" (Handbook 41). Handbook 60 recommends standards of safety set forth by the National Committee on Radiation Protection and is intended primarily for the protection of the radiation worker and the public. *Government Printing Office, Washington 25, D. C., $0.20.*

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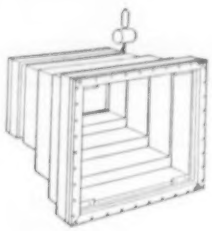

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Radiation shielding compound. Leadcast A, a thermosetting casting compound 93% lead by weight and with a density of 6.6 gm/cm³, can be molded with 1-mil tolerances, has 0.2% shrinkage. Gels at room temperature in 1–2 hours.—Telectro Industries Corp., 35–16 37 St., Long Island City 2, N. Y.

Radiation shield. Adjustable lead shield is made of interlocking sections; 5 different types, weighing 25–55 lb each, are available. Sections are cast of antimonal lead, chrome-plated.—Atomic Center, 489 Fifth Ave., New York 17, N. Y.

Moisture meter. Nuclear moisture meter, consisting of ratemeter, probe-type sensing element, and encapsulated fast-neutron source, quickly measures moisture content on pre-calibrated curve. Surface or depth measurements possible.—Wm. B. Johnson & Associates, Inc., Empire State Building, New York, N. Y.

NEW MATERIALS

Porous aluminum. New method produces porous aluminum and aluminum alloy sheets with pore openings of 5–150 microns. Readily formed and welded.—Micro Metallic Corp., 30 Sea Cliff Ave., Glen Cove, N. Y.

Copper clad steel. Copper clad steel sheet and tubing can be welded by inert gas arc systems, electrical resistance methods, is lighter, stronger than solid copper. Clad Invar and stainless steel also available.—Joseph Kinney Co., Inc., Carnegie, Pa.

Nickel-base alloy. Nionel (40% nickel, 21% chromium, 3% molybdenum) is highly corrosion resistant. Available in standard mill forms. Cold rolled sheets, annealed, have tensile strength of 94,000 to 95,500 psi, elongation of 44.0 to 49.0.—International Nickel Co., Inc., 67 Wall St., New York 5, N. Y.

Polyurethane foam. New cellular synthetic can be produced in densities of 2–10 lb/ft³, slabs of any length. Good thermal insulating power, K factor of about 0.023 kg cal/Mh° C.—American Collo Corp., 525–535 Oritan Ave., Ridgefield, N. J.

Nonplasticized polyvinylchloride. New technique permits economical

Commercial-Grade Zirconium Products

Reactor-grade low-hafnium zirconium at present holds the attention of reactor designers because of its low thermal neutron cross section (see "Zirconium—What is its Future," NU, Feb. '56, p. 45). Zirconium containing the naturally occuring amount of hafnium (2–2½%) may eventually attract more serious consideration. It has the same good high-temperature-water corrosion resistance and can be used where capture cross section is not a concern. The table below lists some suppliers and their products.

INGOTS	*Size*	*Price*
Carborundum Metals Co., Inc., P. O. Box 32, Akron, N. Y.		
Double arc melted; machine or arc conditioned	400–600 lb, 12-in. diameter; min. 500-lb order	$14.40/lb, f.o.b. Akron, N. Y.
Metal Hydrides, Inc., Beverly, Mass.		
30/70 Zr-Cu (99% purity)		
59/41 Zr-Cu (98.5% purity)		

SPONGE	*Price*
Carborundum Metals Co., Inc.	
Brinell hardness = 165 max. on arc-melted test ingot; through ⅜ in. on 20 mesh	1–74 lb, $10.00/lb; 75–600 lb, $9.00; 600–3,000 lb, $8.00; >3,000 lb, $7.50; f.o.b. Akron, N. Y.

POWDER	*Spec's*	*Price*
Carborundum Metals Co., Inc.		
	20 mesh and finer; H_2, O_2, and N_2 higher than in sponge; other impurities are similar	<75 lb, $5.00/lb; 75–500 lb, $4.50/lb; >500 lb, $4.00/lb; f.o.b. Akron, N. Y.
Metal Hydrides, Inc.		
Zr	Typical screen analysis: 80% −325, 12% −200 +325; 8% −150 +200; 96–98% Zr + Hf	
30/70, 50/50, and 70/30 Zr-Ni	95–96% purity	

CHEMICALS	*Spec's*	*Price*
Carborundum Metals Co., Inc.		
ZrO_2	99+% ZrO_2 + HfO_2	>300 lb, $1.50/lb, f.o.b. Akron, N. Y.
$ZrCl_4$	97–99% $ZrCl_4$ + $HfCl_4$	Carload, $0.33/lb; 300 lb, $0.35/lb; f.o.b. Akron, N. Y.
Zirconium carbonitride (ZrN + ZrC)	74.5–80% Zr as carbide and nitride	1–10 lb, $1.00/lb; 2,000 lb and over, $0.30; f.o.b. Akron, N. Y.
Kawecki Chemical Co., 220 E. 42 St., N. Y. 17, N. Y. (f.o.b. Boyertown, Pa.)		
Ammonium zirconium fluoride		20,000 lb, $1.00/lb; 400 lb, $1.50/lb
Potassium zirconium fluoride		20,000 lb, $0.50/lb; 400 lb, $0.55/lb
Sodium zirconium fluoride		20,000 lb, $0.60/lb; 400 lb, $0.65/lb
Zirconium hydroxide, high purity		20,000 lb, $1.50/lb ZrO_2 content; 400 lb, $2.00/lb
Zirconium oxide, high purity		20,000 lb, $1.60/lb; 400 lb, $2.10/lb
Zirconium oxyfluoride		100–1,000 lb, $4.50/lb
Zirconium tetrafluoride		100–1,000 lb, $5.00/lb

(Continued on p. 108)

Radiation Applications

A monthly technical report on industrial uses of radiation.

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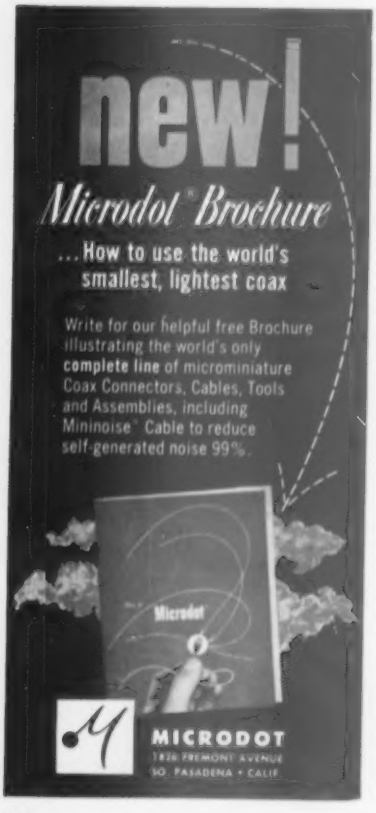
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CHEMICALS (cont.)	*Spec's*	*Price*
Metal Hydrides, Inc.		
ZrB_2	76% Zr + Hf	
ZrH_2	4.0–5.0 micron powder (Grade Z), 95.5% Zr + Hf	
	2.5–3.0 micron powder (Grade AZ), 95.5% Zr + Hf	
	2.8–3.5 micron powder (Grade E), 96.5% Zr + Hf	
Titanium Zirconium Co., Inc., Flemington, N. J.		
C.P. oxide	Powder, 99.66% ZrO_2 + HfO_2	$1.50/lb. f.o.b. Flemington, N. J.
Carbonate	18–21% ZrO_2 + HfO_2	$0.30/lb, f.o.b. Flemington
Sulfate crystals	32.8% ZrO_2	<100 lb, $0.75/lb; >10,000 lb, $0.365/lb

FABRICATED PRODUCTS	*Spec's*	*Price*
Allegheny Ludlum Steel Corp., River Road, Brackenridge, Pa.		
Forgings and rolled bar (annealed and descaled)	Slabs or sheet bars	$15/lb, f.o.b. Watervliet or Dunkirk, N. Y.
	Rounds, squares, etc. (¼–8 in.)	$21–15/lb, f.o.b. Watervliet or Dunkirk
Strip—hot rolled and/or cold rolled (annealed and descaled)	Square edge	$19.50–22.00/lb, f.o.b.
	Heavy gage strip	0.157–0.187 in. thick ⅜–4½ in. wide W. Leechburg, Pa.
	Flat bar	0.188–0.300 in. thick, 2⅞–4½ in. wide $29.50–32.00/lb, f.o.b. W. Leechburg
	Universal edge	
	Heavy-gage strip	0.157–0.187 in. thick, 3–10 in. wide $18–20/lb, f.o.b. W. Leechburg, Pa.
	Flat bar	0.157–1.000 in. thick, 3–10 in. wide $18–20/lb, f.o.b. W. Leechburg
	Sheared edge	
	Standard cold-rolled strip	0.156–0.005 in. thick, up to 24 in. wide $21–37.50/lb, f.o.b. W. Leechburg, Pa.
Chase Brass and Copper Co., Inc., Waterbury 20, Conn.		
Extruded tubing (conversion basis)	1½-in. min. i.d., 5½-in. max. o.d.; ⅛–½ in. min. wall thickness, depending on o.d.; 1-in. max. wall thickness	Price on request for specific lots
Firth Sterling, Inc., 3113 Forbes St., Pittsburgh 30, Pa.		
Sheet bar		>500 lb, $16.93/lb; <50 lb, $21.16/lb
Forged billets	Up to 625 lb	>500 lb, $16.38/lb; <50 lb, $20.48/lb
Hot-rolled strip	0.100 mil min., 100 in. wide, 600-lb rolls	>500 lb, $18.49/lb; <50 lb, $26/lb
Cold-rolled strip	0.005 mil min. thickness	
Hot-rolled bars	3/16–5 in. diameter, ¼–10 in. square	>500 lb, $16.82/lb; <50 lb, $24.88/lb
Hot-rolled sheet	0.1 in. thick, 36 × 96	>500 lb, $25/lb; <50 lb, $50/lb
Cold-rolled sheet	down to 0.012 in. min. thickness	
Hot-rolled rods	⅜ in. min. diameter; cold drawn and centerless ground to ¼ in. diameter	
Wire	0.010 in. min. diameter	Price on request
Tubing	Extruded—2½–¾ in. diameter; welded—2½–½ in. diameter; both redrawn to 3/16 in. diameter and 0.020 in. wall	>500 lb, $60/lb; <50 lb, $85/lb

molding of rigid PVC into complex shapes. Rigid PVC is rust-proof, corrosion-resistant, less than half the cost, weight, of stainless steel in thickness of comparable strength.—Stokes Molded Products Div., Electric Storage Battery Co., Taylor & Webster Sts., Trenton 4, N. J.

Casting resin. Flexible, high impact strength expoxide casting resin is easily machined, usable over temperature range of −100° F to 400° F.—Emerson & Cuming, Inc., 869 Washington St., Canton, Mass.

Electrical insulation. Supramica, synthetic mica bonded to electrical glass, retains its properties under radiation and temperatures of 1,000° F. Available in rod or sheet, or molded to specification.—Mycalex Corp. of America, Clifton, N. J.

Protective coating. Dip Seal, available in clear or colors, provides a 0.059-in. plastic coating with flash point of 435° F. Film is removed by slitting and stripping off.—Dip Seal Plastics, Inc., Rockford, Ill.

Aluminum putty. Devcon F, approximately 80 percent aluminum, 20 percent plastic, can be used to repair worn or damaged aluminum, steel castings. Hardens quickly, can be machined, is durable and permanent.—Chemical Development Corp., Danvers, Mass.

ELECTRONIC INSTRUMENTS AND APPARATUS

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- **RECORDER**

Model DZ 22

The Model DZ22 Medical Spectrometer is a complete unit for use in radio-active studies, tracing, tumor localization, and other important uses.

This new Medical Spectrometer consists of our DZ21 Spectrometer (combination high voltage supply, linear amplifier, single channel analyzer and count rate meter), DP21 Scintillation Probe, DW7 Esterline-Angus Recorder and a cabinet with casters for holding the above items plus a moveable arm that supports the probe. This moveable arm with the scintillation probe will help you work in cramped areas, or when working over a hospital bed, stretcher cart, or wheel chair.

The features of DZ22 Medical Spectrometer provide the highest count-to-background ratio and highest efficiency of any other comparable equipment. The single channel analyzer feature of the instrument permits counting just the particular energy peak you are interested in, such as, the 364 kev iodine peak, 320 kev chromium, 638 kev iodine or 661 kev cesium, to the exclusion of all background and secondary emissions that peak outside the limits of channel width setting.

The scintillation probe is truly unique. Not only does it have 1″ of lead on all sides of the crystal but there is a 2″ nonactivated Sodium Iodide Crystal used for a light pipe between the activated crystal and the photomultiplier. This provides the equivalent of approximately 1″ of lead shielding in the backward direction and obviates the necessity of encasing the probe in lead to cut down scattered radiation, cosmic background or laboratory background.

The focusing collimator on the front of the probe provides a focal point 1.9 inches in front of the nose and is sharp enough to obtain three dimensional radiation patterns. At the focal point the 50% radiation contour line is only 0.38 inches wide. The 100% contour line is nearly half that. (Refer Detectolab Catalog 5A, and Page 17, Nucleonics, November, 1955).

SPECIFICATIONS

CHANNEL WIDTH STABILITY:	1% of Channel Width Setting.
CHANNEL WIDTH:	Adjustable to 10 volts on 100 unit dial.
HIGH VOLTAGE:	600 to 1300 volts positive with 0.1% regulation.
MAXIMUM COUNTING RATE:	600,000 counts per minute in counting rate position, 60,000 counts per minute in integrate position (100 second preset time on integrate)
COUNT RATE TIME CONSTANT:	10 seconds
CRYSTAL:	NaI (Tl) 2″ x 2″
COLLIMATOR TRANSMISSION:	58%
5% CONTOUR LINE:	Maximum width 1¼″
50% CONTOUR LINE:	Maximum width 0.38″
PROBE BACKGROUND:	75 counts per minute
RECORDER CHART SPEEDS:	¼, 1½, 3, 6 and 12 inches per hour
RECORDER ACCURACY:	1% of full scale

Sales Offices

Electro-Mec Associates, 109 E. Nine Mile Rd., Ferndale 20, Mich., phone—Lincoln 7-1422
Kimball Electronics, Ltd., 209 Alhambra Circle, Coral Gables, Fla., phone—4-9028

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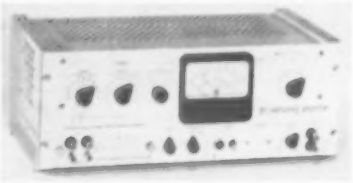
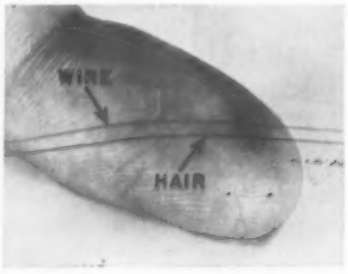
at 900 mc with 10-mc bandwidth.—General Electric Co., Tube Dept., Schenectady 5, N. Y.



D-C Amplifier

Input impedance of $>10^{12}$ ohms and <10 $\mu\mu$f, maximum gain of 160,000, and d-c to 100-kc frequency response characterize the 303 indicating amplifier (above). Plug-in decade shunt converts instrument to micromicroammeter. Zero drift is less than 2 mv/hr. Power amplifier is included for driving recorder.—Keithley Instruments, Inc., 3868 Carnegie Ave., Cleveland 15, Ohio.



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Amplifier. Model HC amplifier and phase-sensitive detector, with 5-μv full-scale sensitivity, is specially designed to measure optical radiation.—Baird Associates, Inc., 33 University Rd., Cambridge 38, Mass.

High vacuum pumps. Hyvac 2 has free air displacement of 20 ls/min, delivers ultimate vacuum of 0.1 micron.—Central Scientific Co., 1700 Irving Park Rd., Chicago, Ill.

Multichannel analyzer. New 256-channel analyzer, based on the Argonne design, has count storage capacity of 2^{18}, uses Wilkinson analog-

to-digital conversion.—Radiation Counter Laboratories, Inc., 5122 W. Grove St., Skokie, Ill.

D-C millivoltmeter. Model J, miniature ruggedized d-c millivoltmeter, reads 500 μv—300 volts with accuracy of 2% of full scale. Designed for panel mounting.—Trio Laboratories, Inc., 3293 Seaford Ave., Wantagh, N. Y.

Transistorized power supplies. Small, lightweight units (4 in.^{3}, about 6 ounces) produce up to 16,000 volts from 1.5 volts of input. Rectangular, cylindrical, or custom-made, can withstand 20,000 G's, have ambient temperature cycle of -25 to 100° C.—Universal Atomics Corp., 19 E. 48 St., New York 17, N. Y.

Electron tube tester. New portable tube tester provides ranges of 60,000, 30,000, 15,000, 6,000, 3,000, and 600 micromhos; a rectifier diode range; and VR range. Separate d-c voltmeter measures grid bias; separate a-c meter measures line voltage at all times.—Hickock Electrical Instrument Co., 10588 Dupont Ave., Cleveland 8, Ohio.

Transistorized random-pulse generator. Portable random pulse generator has full-scale meter and polarity switch, operates from 110-volt line current or flashlight batteries.—Universal Atomics Corp., 19 E. 48 St., New York 17, N. Y.

High resistance megohmmeter. Model L-7 megohmmeter, with ranges to 5×10^{13} ohms and continuously variable test voltages of 100–600 volts d-c, uses 115 volt, 50/60 cycle power.—Industrial Instruments, Inc., Cedar Grove, N. J.

LABORATORY INSTRUMENTS AND APPARATUS

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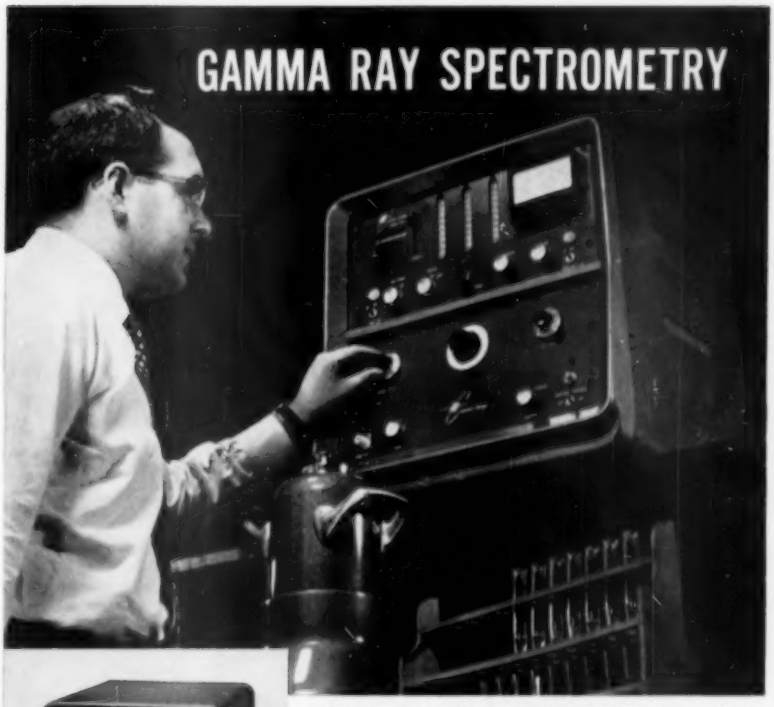
Freezing-Point Meters

For determining chemical purity Cryoscope unit measures freezing point to within 0.001° C from +20 to



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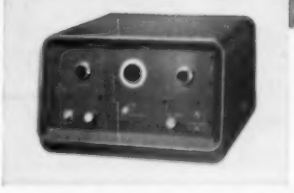

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$$L(v,\gamma,\delta_1,\frac{d\phi}{dt},\rho)=\left(L(v_1,\gamma_1,\delta_1,\sigma,\rho)+L_v\bar{v}+L_\gamma\bar{\gamma}+L_{\delta_1}\bar{\delta}_1+\delta\phi\frac{d\bar{\phi}}{dt}\right)\left(-R_n\frac{\sum_{i=1}^{n}\frac{X_i}{R_i}}{\sum_{i=1}^{n}\frac{1}{R_i}}\frac{(-A)}{(1-A)+R_n\sum_{i=1}^{n}\frac{1}{R_i}}\right)$$

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—30° C in 1 min. Related instrument is Fiske Osmometer for determining osmotic pressures, molecular weights, etc., by freezing-point. —Advanced Instruments, Inc., 21 Oakcrest Rd., Boston 92, Mass.

LITERATURE AVAILABLE

Pressure controller. Indicating pressure controller, in ranges from 0–50 to 0–200 psi, with on-off or 10% throttle control, is described in bulletin 7040. 2 p.—Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne and Windrim Aves., Philadelphia 44, Pa.

Radiation processing. Booklet surveys radiation machines and their application. 32 p.—High Voltage Engineering Corp., Cambridge, Mass.

Laboratory equipment. Laboratory furniture and equipment for all research are described in catalog. 12 p. —Metalab Equipment Co., Div. of Norbute Corp., 214 Duffy Ave., Hicksville, N. Y.

Electro-hydraulic actuator. Catalog 22 describes actuator for positional control at high response speeds, of butterfly valves, other large masses. —Weighing & Control Components, Inc., 64 Fulmor Ave., Hatboro, Pa.

Test instruments. Electronic test instrumentation described in catalog. 8 p.—Shasta Div., Beekman Instruments, Inc., P. O. Box 296, Station A, Richmond, Cal.

Resistors. 5 publications give comprehensive data on resistors. Resistor Engineering Guide gives data on all IRC resistors and special products. —Internationational Resistance Co., 401 N. Broad St., Philadelphia 8, Pa.

Heat detection. Bulletin 9320 describes high speed radiation detector which responds to 98 percent of any temperature change in less than one-half second.—Minneapolis-Honeywell Regulator Co., Wayne and Windrim Aves., Philadelphia 44, Pa.

Ceramics. Booklet describes the use of porcelain, stoneware, ceramic coatings, impervious graphite, and alumina ceramics in chemical equipment. 16 p.—General Ceramics Corp., Keasbey, N. J.

Gages. Bulletin describes, gives specifications for Acragage pressure gages. 4 p.—Norden-Ketay Corp.,

Instrument and Systems Div., Wiley St., Milford, Conn.

Boiler plant instrumentation. Catalog gives data, including photos and schematics, on power plant instruments and control systems. 24 p.—Hayes Corp., Michigan City, Ind.

Automation. Application of punched tape control system to a turret lathe is described in reprint. 8 p.—Barnes Engineering Co., 30 Commerce Rd., Stamford, Conn.

Valve selection chart. 18" × 24" wall chart gives tabular data to simplify selection of forged needle, bar stock, and toggle valves.—Hoke, Inc., 233 S. Dean St., Englewood, N. J.

Piping flexibility analysis. Brochure describes analysis that can reduce process and power piping costs in materials, design, and construction. 12 p.—M. W. Kellogg Co., 225 Broadway, New York, N. Y.

Heat equipment. High velocity combustion equipment is described in bulletin 108. 8 p.—Thermal Research & Engineering Corp., Conshohocken, Pa.

Receiving-type tubes. RIT-104 describes 130 small industrial tubes for industry and communications; chart lists RCA types for government end use only. 20 p.—Commercial Engineering, Tube Div., Radio Corporation of America, Harrison, N. J.

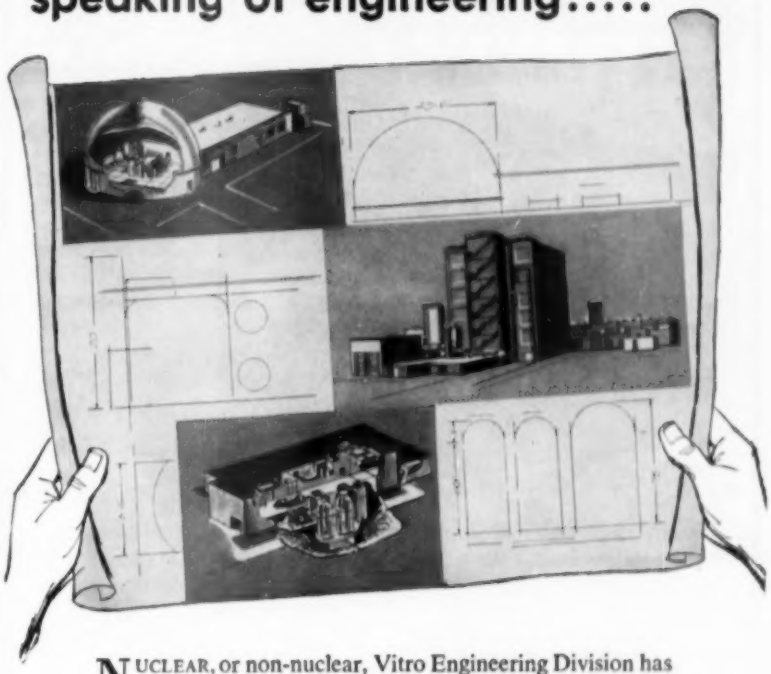
Heat exchange. Heat transfer surface consisting of arrangement of inner fins in conjunction with outer fins is described in folder.—Bush Manufacturing Co., West Hartford, Conn.

Mechanical seals. MS-9 54 describes external rotating mechanical seals for use in handling acids, alcohols, alkalis, hydrocarbons. 8 p.—United States Gasket Co., Camden 1, N. J.

Temperature controls. Description, general specifications, and instrument selection chart given in catalog of differential expansion temperature controls.—Burling Instrument Co., 16 River Rd., Chatham, N. J.

Standard conversion tables. Bulletin F7255 gives thermocouple temperature-milivolt equivalents, with temperatures expressed on International Temperature Scale of 1948,

speaking of engineering.....



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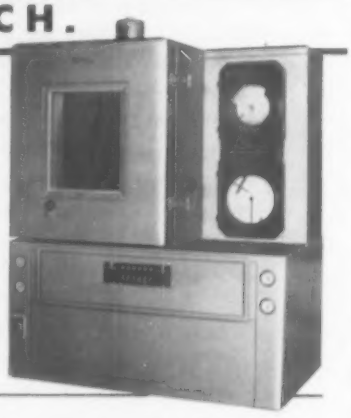

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electromotive force in absolute units. 16 p.—Barber-Colman Co., Wheelco Instruments Div., Rockford, Ill.

Gamma-ray radiography. Portable, shielded gamma-ray radiography sources using Co^{60}, Ir^{192}, and Cs^{137} are described in detailed booklet. 24 p. Units are manufactured by M. W. Kellog Co.—Metal and Thermit Corp., 100 E. 42 St., New York 17, N. Y.

Special metals. Production and processing of made-to-order metals in experimental quantities is described in booklet. 16 p.—Allied Products Div., Hamilton Watch Co., Lancaster, Pa.

Thermocouple wires. Conductor specifications, recommended insulations for operating temperatures of thermocouple wires listed in bulletin 1701.—Revere Corporation of America, Wallingford, Conn.

Nuclear reactor simulator. Folder describes, illustrates nuclear reactor simulator whose components are reported to be identical to those in research reactors. 4 p.—Leeds & Northrup Co., 444 N. 16 St., Philadelphia 30, Pa.

Relays. Bulletin gives specifications, technical data for many relay types. 4 p.—AEMCO, Inc., Mankato, Minn.

Scintillation counter. Brochure describes scintillation counter for oil, uranium prospecting.—Chatham Electronics, Div. of Gera Corp., Livingston, N. J.

Oscillographic recording equipment. Sanborn "150" series oscillographic recording systems and equipment described in booklet; price list included. 16 p.—Sanborn Co., Industrial Div., 195 Massachusetts Ave., Cambridge 39, Mass.

Liquid scintillation spectrometer. Folder describes equipment for counting low-energy beta emitters in solution with liquid phosphors. 6 p.—Packard Instrument Co., P. O. Box 428, LaGrange, Ill.

INDUSTRY NOTES

▶ **Edward Valves, Inc.**, a subsidiary of **Rockwell Manufacturing Co.**, will complete an addition to its laboratory in the spring. This will include a section for development, assembly and final testing of nuclear power valves. Edward builds special high-pressure,

high-temperature valves, such as for atomic-powered submarines.

▶**High Voltage Engineering Corp.** has begun construction of an 88,000 ft² plant that will contain enough test vaults to allow simultaneous operation of 16 accelerators. The facility, including equipment, will cost nearly $2,000,000.

▶**Murray E. Volk** has organized the **Volk Radiochemical Co.,** with offices at 5412 N. Clark St., Chicago 40, Ill. The new company will specialize in the manufacture and supply of labeled compounds and allied services. Dr. Volk had been associated with Nuclear-Chicago.

▶**General Mills Research Laboratories** has installed nearly 4,000 curies of high-activity cobalt-60 to be used in studies of chemicals and food processing. The cobalt will be kept submerged under a 12-ft water shield in a 4- × 6-ft well.

▶**Leeds & Northrup Co.** will supply complete instrumentation for a critical assembly to be owned and operated by **Combustion Engineering, Inc.,** of New York. Essentially a zero power nuclear reactor operating at very low wattage, the facility will be used for low power level tests of typical cores for submarine nuclear propulsion unit to be built for AEC.

▶**Nuclear Development Corporation of America,** White Plains, N. Y., has obtained financing from a group composed of Laurence S. and David Rockefeller; J. H. Whitney & Co.; William A. M. and Shirley C. Burden; Smith, Barney & Co.; and C. A. Unterberg, Towbin Co. The capital will be used for development of reactor testing and manufacturing facilities in 1956 expansion program.

▶**Nuclear Consultants,** St Louis, has moved to quarters with larger office, laboratory, and consulting areas, including laboratory for producing radiochemicals and radiopharmaceuticals.

▶**Jack Carlin, Dick O'Toole, and Louis Mead** have established **Atomic Associates, Inc.,** manufacturer's representatives for firms in the nuclear field exclusively, with offices in New York, Philadelphia, and Boston. One of their principal accounts is Atomic Instruments Co., Cambridge, Mass. They formerly were territory managers for Tracerlab.

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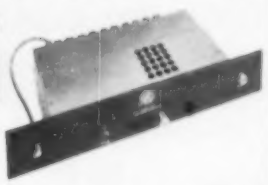

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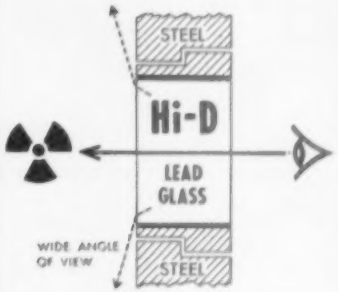

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PATENTS

Apparatus for Measuring Solid Levels in Tanks

U. S. 2,713,124, issued to Ollie W. Graham and assigned to Instruments, Inc., describes a device using a radioactive source and a detector for determining the level of solids in a large storage tank or reactor.

As an example, Fig. 1 shows how the catalyst level might be measured in a catalytic cracker. Inserting the source and detector in vertically aligned wells in the side of the cracker permits using a minimum of radioactive material.

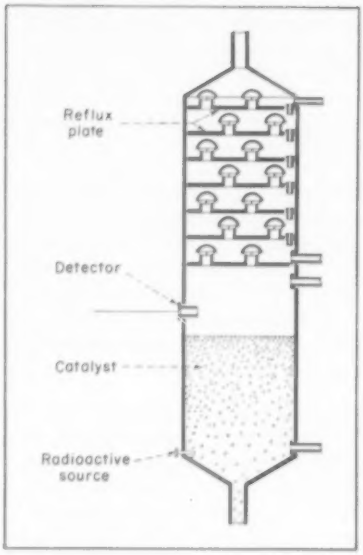

FIG. 1. Arrangement for measuring solid (catalyst) level

Radioactivity Flow Meter

In various hydrogenation systems, hydrogen-containing gas is recycled under pressures as high as 5,000 lb/in² and sometimes over 1,500° F. For measuring flow rate under these conditions, rotameters lack accuracy, metal manometers for such high pressures are not generally available, and glass units are a source of danger. In U. S. 2,714,168 (assigned to The Texas Co.), W. R. Hencke and E. L. Cole suggest a differential manometer using a floating radioactive pellet and a detector (see Fig. 2).

The manometer is connected to the fluid conduit at opposite sides of an orifice plate. The manometer liquid, e.g., mercury, rises or falls according to the pressure differential across the orifice plate, carrying a radioactive source on the mercury surface in the low-pressure leg. The detector is moved vertically to follow the source. A by-pass valve is provided above the orifice.

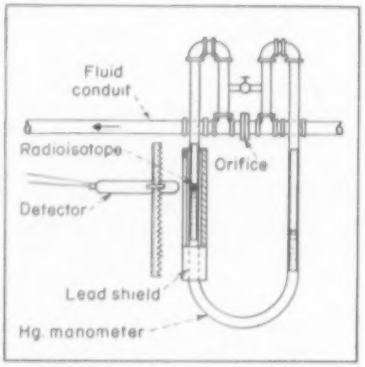

FIG. 2. Radioactivity high-pressure flow meter

Radio-Pulse System Uses Radioactive Material

U. S. 2,720,582 (issued to E. G. Linder and S. M. Christian and assigned to Radio Corporation of America) describes a radio-pulse generator and transmitter that operates by storing radiation energy in a high-voltage capacitor.

The capacitor can be two concentric electrodes, the inner one coated with radioactive material and the outer serving as a radiation shield. The radioactive charge is converted to oscillatory pulses by a high self-restoring resistance, in circuit with the capacitor and a resonant circuit, whose breakdown voltage is less than the maximum emission voltage of the radioactive material. The resistance could be a gas at low pressure in a magnetron tube or between electrodes of a spark gap in an oscillatory circuit having lumped constants.

As examples, a 50-kw peak-power pulse may be obtained every 16.7 sec by using 100 curies of a beta emitter, or every 167 sec by using 10 curies of the emitter.

The capacitor, the resonant tube or circuit, and an antenna can be combined as a hermetically sealed unit for use as an unattended radio beacon in remote areas.

Preparing Labeled Glutathione

Glutathione, a sulfur-containing tripeptide, assists in providing protection in cases of extended radiation exposure and reduces the requirement for plasma and whole blood in injuries involving shock. Thus, radiosulfur-labeled glutathione is useful for investigating its physiological action.

Previous methods for isolating labeled glutathione have required large quantities of yeast cells grown in large volumes of S^{35}-sulfate-containing media. L. Laufer and S. Gutcho describe a biosynthesis providing significant quantities at high specific activity (U. S. 2,711,989, assigned to the Secretary of the Navy).

The process is as follows: (1) Grow yeast cells 24 hr on 100 ml medium [B. Olson, M. Johnson, *J. Bacteriol.* **57**, 235 (1949)]. (2) Harvest cells and wash by centrifugation. (3) Plasmolyze packed cells by adding 0.2 vol. Piries's solution. (4) Collect supernatant and 3 washes of 3–5 ml each by centrifugation. (5) Add carrier glutathione. (6) Precipitate cuprous glutathione by adding cuprous sulfite reagent at *p*H 1.5. (7) Recover cuprous glutathione by centrifugation and wash. (8) Suspend washed cuprous glutathione in water and gas with H_2S to decompose and precipitate Cu_2S. (9) Remove and wash Cu_2S by filtration; combine supernatant and wash. (10) Add carrier glutathione calculated for desired specific activity. (11) Treat with carbon. (12) Concentrate *in vacuo* and crystallize from water or water-ethanol.

Neutron-Sensitive Scintillators

Lithium-containing phosphors have poor resolution and pulse height for neutrons. In U. S. 2,719,127, James Schenck (Oak Ridge) claims that lithium iodide activated by europium has considerably greater luminescence efficiency and can be made into an optically clear crystal.

The europium concentration preferably should be in the range 0.001–0.1 mole per cent; higher proportions may discolor the crystal. The finished crystal should be at least 1 mm in any dimension.

* * *

These descriptions are based on abstracts furnished by Melvin Nord, Registered Professional Engineer and Patent Attorney, Detroit, Mich.

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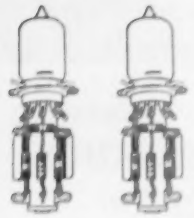

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NEWSMAKERS

Walter A. Hamilton, a member of the staff of the Joint Committee on Atomic Energy since 1947, has joined the executive staff of Nuclear Development Corp. of America (NDA), White Plains, N. Y.

John H. Harley of AEC's New York Operations Office was honored by the Washington Junior Chamber of Commerce as one of ten outstanding Federal civil servants under 40 years of age. Chief of the analytical branch of the Health and Safety Laboratory, he was chosen for his development of standards and techniques to protect atomic energy workers, and for his study of radioactivity in sea water and marine life.

John W. Webster, formerly of Phillips Petroleum's Atomic Energy Division at Arco, Idaho, is now head of reactor-physics work at American-Standard, Redwood City, Calif.

Paul F. Genachte has been appointed acting director of the atomic energy division at Chase Manhattan Bank in New York.

Henry H. Hausner, formerly manager of engineering at Sylvania's atomic energy division, has become general manager of the nuclear engineering division of Penn-Texas Corp.

John M. Warde, formerly head of the Ceramic Laboratory at Oak Ridge National Laboratory, has been transferred by Union Carbide & Carbon Corp., operators of ORNL for AEC, to its Union Carbide Ore Co. He will be concerned with raw-materials problems.

An enlarged research and development program at Alco Products, Inc., will be headed by **Capt. C. S. Seabring, USN (ret).** His responsibilities will include some aspects of Alco's nuclear power projects as well as the company's gas-turbine development program. **Dana T. Hughes** has been named director of Alco's public relations; his place as news bureau manager is being taken by **Roger C. Witherell.**

Allan T. Gifford has been named AEC's director of operations at Hanford, succeeding **D. G. Sturges,** who has become manager of the new products branch of the Carborundum Co. **P. G. Holsted** moves up to deputy director of Hanford operations for AEC.

Edward G. Lowell, a chemical engineer, has joined the technical staff at Atomics International division of North American Aviation.

NUCLEAR CALENDAR

March 19–21—Reactive Metals Conference (AIME), Buffalo (*Statler*).*

March 19–22—Institute of Radio Engineers, annual meeting (Professional Group on Nuclear Science meets on 20th), New York (*Waldorf*).*

March 21–23—Eighteenth Annual American Power Conference (Illinois Tech with 14 other universities, 9 technical societies), Chicago (*Sherman*). Insuring nuclear power plants, research in nuclear power, the roles of government and industry in its development. Contact R. A. Budenholzer, Illinois Tech, 35 W. 33rd St., Chicago 16.

April 3–7—6th Annual Conference on High Energy Nuclear Physics (AEC & Natl. Sci. Foundation), Rochester, N. Y.*

April 5–6—Conference on Magnetic Amplifiers (AIEE, IRE, ISA), Syracuse, N. Y.*

April 16–18—First Annual Conference and Exhibit of ASME Gas Turbine Power Division, Washington (*Statler*). Session on nuclear power and closed cycles 17th, forenoon. Contact ASME.

April 17–18—Regional conference, Atomic Industrial Forum, Atlanta, Ga. On 19th the conference moves to Oak Ridge.*

May 14–16—Conference on Basic Mechanisms in Radiobiology (National Research Council), Highland Park, Ill.

May 15–16—Industrial Nuclear Technology Conference (co-sponsored by Armour Research Foundation and NUCLEONICS), Chicago.*

May 17–19—Annual meeting, Radiation Research Society, Chicago (*Palmer House*).

June 6–8—American Nuclear Society, 2d annual meeting. Chicago (*Palmer House*). Contact Exec. Secy. ANS, Box 963, Oak Ridge, Tenn.

June 11–23—Symposium on High Energy Physics (European Organization for Nuclear Research-CERN), Geneva. Novel features in the design and techniques of high energy accelerators. Contact CERN, Box 25, Geneva 15, Switzerland.

* For details see February issue, p. 78.

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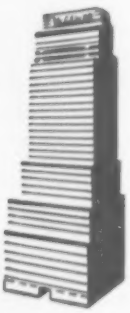

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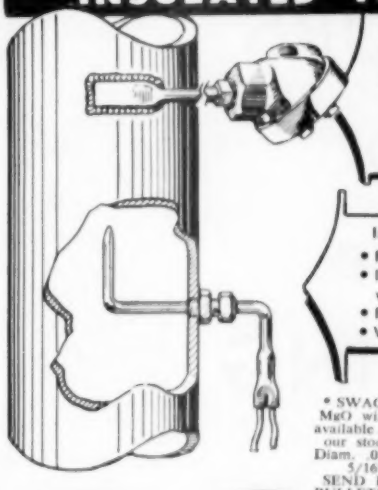

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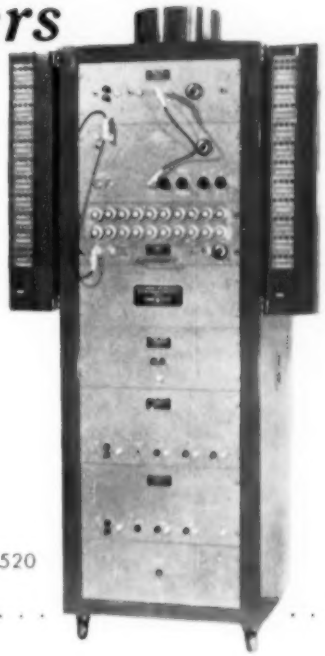
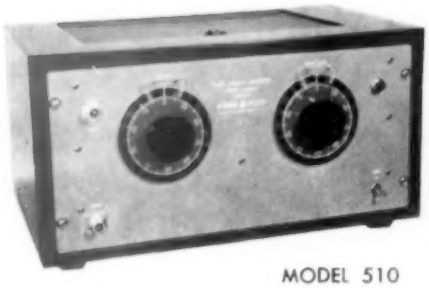


MODEL 520



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- Used for studies of energy distribution of nuclear particles. Permits separate counting of isotopes in mixtures. Reduces background count to permit counting of low concentration or low energy isotopes.
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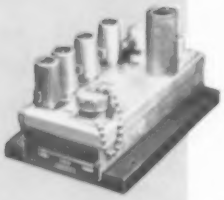
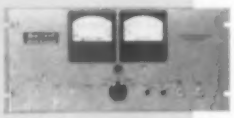


A1A Preamplifier—wide-band pulse amplifier of moderate gain. Low output impedance for feeding long coaxial cables. Small size; can be mounted near neutron detector, or adapted to proportional counter. Similar to Oak Ridge Model Q-541.

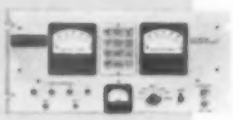
A1D Linear Pulse Amplifier—for amplifying pulse output of A1A Preamplifier. Feedback design gives high linearity, stability, accurate reproduction of input pulse. Similar to Oak Ridge Model Q-1326.

Log Count Rate Amplifier—measures average rate of a series of pulses . . . derives a usable signal from pulse output of the linear amplifier. Two d-c stages produce large signal easily differentiated to obtain period time.

Low Level Period Amplifier—differentiates log count rate meter output to give a period signal for safety during startup. Inverse time delay gives quick shutdown for excessively short period . . . waits longer for longer periods.



Log N and Period Amplifier—combines two functions in a single unit. Used with ion chamber to produce signal proportional to log of neutron flux, to feed log power level recorder. This signal is differentiated to obtain period signal, which is then amplified to actuate a recorder.



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